Draft Report

Terms of Reference Defining Basins and Agreeing on their Boundaries within the Region of the Southern African Development Community

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Terms of Reference
Defining Basins and Agreeing on their Boundaries within the Region of the Southern African Development Community

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1. Introduction

1.1 Background

For the countries of the Southern African Development Community (SADC) region to move ahead with improved water management in their river basins, the boundaries of these basin need to be defined, mapped and agreed. USAID seeks to provide assistance to the SADC Water Sector Coordinating Unit (WSCU) to carry out a process of defining and agreeing on basin boundaries in southern Africa. This Terms of Reference (TOR) lays out three approaches as to how the WSCU might proceed.

It is understood that the process of defining boundaries will be complex and politically sensitive. The technical tasks will have to be balanced with concerted efforts to achieve local ownership and consensus on both the technical approach and the outcome of the boundary definition exercise. To the extent that objective tools—such as a geographic information system (GIS)—are utilized and accepted by all key parties, this process should be somewhat easier.

This draft TOR is written in an advisory tone—laying out the current state-of-the-art with respect to GIS and remote sensing technology and boundary mapping. Its intent is to inform decision-makers within the region before asking them to decide upon a course of action. Once a choice has been made regarding the best path to follow for completing the river basin boundary definition process, the TOR can be adjusted and refined to serve as a blueprint for the conduct of this important exercise.

The report is organized as follows:

Section 2. Geographic Information System Development examines significant issues that should be thoroughly addressed prior to commissioning the development of a geographic information system for the WSCU and the RBMCs.

Section 3. SADC, the WSCU and GIS Technology presents a general program of GIS implementation for SADC and the WSCU.

Section 4. Water Resource Databases for SADC contains information on two databases being developed by the FAO and other cooperating agencies that should be of use to those assigned the task of defining the boundaries for the 15 shared river basins in the SADC region. This material indicates that much of the work described herein has already been done. Whether or not it has been done at a level of accuracy that is sufficient to the needs of SADC and the WSCU needs to be determined.

Section 5: River Basin Boundary Mapping: Two Approaches—presents two approaches for the production of shared river basin boundary maps. The first envisions the production of the maps as an integral part of the implementation of a comprehensive GIS program for the WSCU. The second calls for the production of the maps independent of the implementation of a GIS.

Section 6: Detailed Terms of Reference presents three TORs for the production of shared river basin boundary maps. The first envisions the production of the maps as an integral part of the implementation of a comprehensive GIS program. The second calls for the production of the maps independent of the implementation of a GIS. The third calls for the production of boundary definitions for one or two selected basins as a pilot project and the simultaneous carrying out of a feasibility study designed to determine the practicality of developing a comprehensive geographic information system for the WSCU.

Attachment I: Satellite Imagery and Basin Boundary Mapping discusses the suitability and utility of remotely sensed data and images for the proposed undertaking.

Attachment II: Current Remote Sensing Platforms, provides recent information on the availability of earth-imaging satellites, data from which could prove helpful for the production of the shared river basin boundary maps and as a background for WSCU's geographic information system.

1.2 Modification to the TOR Resulting from the May Review by WRTC

An earlier draft of this report was discussed at a meeting of the WRTC in May 1999. A request was made at that meeting for an approach that would allow mapping to begin on a pilot basis immediately, while simultaneously (and independently) allowing the WSCU to investigate the feasibility of adopting a region-wide GIS approach. Section 6.3 responds to that request.

The pilot project element calls for the mapping of the boundaries of "selected" basins. As this is a pilot, its scope should be limited to one or at the most two river basins. When selecting the basins to be mapped during the pilot, WSCU should consider selecting basins that meet the following criteria:

- Basins should cover some part of two and no more than four countries. This will reduce the complexity of the approval task, but still allow for the testing and development of workable approval procedures.

- Basins should be of average size. Neither the largest nor the smallest basin should be mapped during the pilot project.

- If two basins are to be mapped, they should not be adjacent to each other and their geography should be markedly different. This will provide a greater diversity of experience on which to base future cost estimates than would the mapping of adjacent and geographically similar basins.

- Opportunities should be sought to link the boundaries definition exercise with other USAID-sponsored tasks supporting implementation of the SADC Protocol on Shared Watercourse Systems.

The GIS feasibility element calls for a *Needs Analysis*, a *Data Availability Survey*, an analysis of equipment and staffing requirements, and a cost-benefit study.

1.3 Other Issues Raised at the 12 May Review by WRTC

During its review of the first draft of this document, the SADC Water Resources Technical Committee (WRTC) raised several technical issues regarding the processes proposed in the first draft for boundary definition. Those issues were:

- the need for ground truthing,
- the question of how to handle the mapping of both surface water and groundwater, and
- a desire to define in some detail the procedures that will be used to obtain approval of the completed boundary definitions and the technical procedures used to produce them before boundary mapping begins.

Guidance on the management and institutional location of a GIS activity, if one were to be established at some future date, was also sought.

Ground Truthing

Concern was expressed that the "GIS Approach" could suffer from weak ground truthing if not handled very carefully. This concern appears to have arisen from a less than complete understanding of what was proposed for both approaches (Sections 5.1 and 5.2). Neither approach is inherently more accurate or inaccurate than the other. Satellite imagery could well be used in both approaches. Whenever satellite imagery is used, it should be subject to some ground truthing. The amount of ground truthing to be used is a matter to be addressed in the technical specifications (Task 4, "GIS Approach" or Task 2, "Simple Mapping Approach"). The final mapping specifications should specify the level of ground truthing expected of the mapping contractor.

Obviously, the more ground truthing required, the more accurate will be the final boundary definitions. Equally obvious, the more ground truthing required, the more expensive will be the boundary definition process.

The question of how much ground truthing to require of the mapping contractor is a managerial and not a technical issue, and should be handled as such.

Surface Water and/or Ground Water Boundary Mapping

The issue of whether to limit boundary mapping to surface water basins or to include ground water resources was also a concern of some members of the WRTC.

From the perspective of choosing among the alternative mapping approaches described herein, this is not an issue. The mapping of the basin boundaries for surface water resources is a relatively simple and straightforward technical task—one that can be carried out independently of the mapping of ground water resources. The mapping of ground water resources is a more complex technical undertaking—one requiring additional tools and technical expertise. Even if the final technical specifications require the mapping of both sets of boundaries, their mapping will in all likelihood be carried out independently.

The decision as to whether to map surface water boundaries and/or ground water boundaries is a political and economic one. Either of the proposed boundary determination methods proposed can be used regardless of that decision. If both sets of boundaries are to be mapped, the technical specifications developed for either approach (Task 4, "GIS Approach" or Task 2, "Simple Mapping Approach") should so specify.

One major advantage of the "GIS Approach" over the "Simple Mapping Approach" would be its ability to quickly and simultaneously display both sets of boundary maps on a single screen, and to automatically display and compute areas of overlap. This cannot be done as easily with the hard copy maps prepared using the "Simple Mapping Approach."

Boundary Definition Approval

The members of the WRTC are understandably concerned with the question of obtaining approval of the boundary definitions, once the boundary mapping has been completed. This is a political and/or legal issue and need not be resolved before a decision is taken on how to proceed with basin boundary mapping.

Decisions as to what and how to map can be made intelligently and safely without resolving this issue first. In fact it may be wise to table this issue until the boundary mapping process is well under way, for the approach used to "sell" the completed boundary definitions will undoubtedly depend to some degree upon information uncovered and lessons learned during the actual physical mapping process.

It is for this reason that the proposed TORs call for the consultant to develop "marketing plans" (Task 6, "GIS Approach" or Task 4, "Simple Mapping Approach") for obtaining approval of the technical process and the completed boundary definitions—only after the mapping of the boundaries has been completed.

An advantage of the "GIS Approach" over the "Simple Mapping Approach" would be its ability to prepare a variety of displays and reports explaining just how the boundaries were produced to support the approval process.

Assignment of Responsibility for GIS Activity

Members of the WRTC also requested guidance on the assignment of responsibility for overseeing the implementation of GIS technology. More specifically, they requested guidance on whether to form a separate GIS technical unit or to assign responsibility to an existing Water Sector management/coordinating unit. Section 2.3, which has been added to this version of the TOR, provides guidance on this matter. This same section also addresses the role that national mapping agencies and mapping departments should have in the GIS implementation process.

2. Geographic Information System Development

2.1 GIS Technology

During the last decade, GIS technology has come to be widely recognized and accepted throughout the world as a useful, if not essential, tool for natural resource management. GIS technology is unique because it permits users to link image, graphic and textual data in ways not possible with standard information systems. These links permit the manipulation and analysis of diverse data sets in ways that were heretofore impractical, if not impossible. GIS technology also enables users to prepare stunning visual presentations that give life and meaning to the data in the spatial database and the results of any analysis performed with those data.

GIS technology does this through the use of geographical indices that are most commonly, but not always, the geographical or map coordinates of points and lineal or areal features of interest. One of the strengths of a properly constructed and well maintained geographic information system is its ability to support the development of profession specific applications as diverse as water resource management and urban planning" all designed from the same "Geobase[1]."

2.2 Successful GIS Development

After 25 years and many false starts, experienced practitioners of GIS technology have come to accept the following as rules–of–thumb for the successful development of geographic information systems:

- *Define the purpose of the proposed GIS before you do anything else.* There is no such thing as a generic geographic information system. Those who fail to carefully and thoroughly define the applications to which they propose to put their geographic information system frequently experience cost overruns, time overruns, accumulation of inaccurate and unneeded data, unsupportable operating costs, and the acquisition of inadequate or unnecessary equipment. This pitfall can be avoided by conducting as realistic and comprehensive a *Needs Analysis* as resources will allow. The more thorough the Needs Analysis, the more successful (useful and cost effective) will be the implementation of the subsequent GIS program.

- *Establish and Install a Strong Management Team.* The development of a geographic information system of the size and scope needed to support The Environment and Land Management Sector (ELMS), WSCU and the River Basin Management Commissions will be

[1] The term "Geobase" describes the core set of geographic data (geodetic control net, physical geographic features, primary cultural features, etc.) that forms the underlying structure of the GIS. To be cost effective and minimize the potential for future conflict, all operating elements of the Water Sector should share a single Geobase and use only it for the development of profession specific GIS applications.

a complex and costly undertaking. To be successful it will require firm and effective management. By nature large GIS projects involve many organizational entities and threaten many organizational mandates. Successful projects are those that recognize the need for a strong management team and regular coordination—right from the start. Without this coordination resources are most frequently wasted on data collection and data entry, the most expensive part of the GIS implementation process.

- *Identify the data required to support only those applications approved in the Needs Analysis.* A *Data Requirement and Availability Survey* can be prepared in conjunction with the *Needs Analysis*. But it is better undertaken once all potential users of the geographic information system have accepted the *Needs Analysis.* The following traps should be avoided when establishing data requirements:

  - Failing to use a common datum[2] and map projection. Maps covering a region as extensive as SADC or as large as its individual river basins are likely to have been prepared on different geodetic datums or with different map projections. Different datums and different map projections produce different coordinates for the same geographical feature. Stream centerlines, ridgelines, administrative and political boundaries, etc. extracted from maps based on different datums or drawn with different map projections will not join or overlay correctly[3]. Discontinuities on the order of several hundred meters can occur. The Data Requirement and Availability Survey should address these issues and propose specific steps for ensuring that all spatial data in the Geobase is related to a common datum and uses a common map projection.

  - Requiring too much accuracy in the Geobase. Ideally, all Geobases would contain only perfect coordinate data. Practically, this is an unaffordable goal. Properly prepared line maps of the scales shown in the Table below usually suffice for developing Geobase data for regional planning applications. In flat areas, such as river deltas, larger scale maps may be required to obtain adequate elevation data. The Data Requirement and Availability Survey should identify such situations. The Positional Accuracy shown in the following Table is based on International Map Accuracy Standards[4].

[2] A datum is the mathematical model of the Earth used to calculate the coordinates on a map, chart or survey system. All coordinates reference some particular set of numbers for the size and shape of the Earth.

[3] Many national and international organizations are now using Global Positioning Surveys (GPS) to transform available survey and map data to the WGS–84 datum before undertaking the development of wide–area geographic information systems. While this is not a trivial undertaking, SADC should seriously consider doing so if it intends to foster the development of SADC–wide geographic information systems.

[4] Maps prepared to international map accuracy standards have the following accuracy for 90 percent of well–defined points:

Horizontal position—0.5 mm at map scale; Vertical accuracy—within one-half of the map's contour interval; Spot elevations — within one–quarter of the map's contour interval.

Map Scale	Positional Accuracy	Standard Contour Interval
1:250,000	125 meters	100 meters
1:100,000	50 meters	10 meters
1:50,000	25 meters	5 meters

Data describing physical and cultural features can also be obtained from the interpretation of satellite and photographic imagery and the digitization of the results of their interpretation. The accuracy of these data will depend on the scale and type of the imagery used and the care with which the digitization of the interpretation is accomplished. Satellite or photographic images can also be used, as is, to provide a background for vector data or for applications that use raster data directly. The Needs Analysis should realistically assess the level of accuracy required and the need for raster and/or vector data.

In the interest of time, WSCU and the River Basin Management Commissions may find it advantageous to start with a less geographically accurate Geobase than ultimately desirable, knowing that the Geobase can and will be upgraded as part of a routine data maintenance program. For example, the spatial database could be constructed initially with data from 1:250,000 scale sources, then upgraded over time with data from 1:100,000 and 1:50,000 sources.

- Collecting data because "we may need it someday." SADC's first rule for data collection should be, "If you don't need it now, don't collect it now." This rule holds equally for graphic and non-graphic (textual) data. Many existing geographic information systems are encumbered with data that someone thought would be useful someday. The collection and entry of such data are an extravagance that few organizations can afford. Data collection, preparation and entry usually consume 80 to 90 percent of implementation budgets. Moreover, the presence of unnecessary data can slow system performance, and its long-term storage and maintenance will increase operating expenses. "If you don't need it now, don't collect it now."

  SADC's second rule for data collection should be, "Don't collect it, if you are not prepared to maintain it on some reasonable maintenance schedule." As with all information systems, the output of a geographic information system is only as good as the data in the database. Experience suggests that for institutional[5] geographic information systems, if you are not prepared to maintain a specific data element, you probably do not need it. There may be more exceptions to this rule–of–thumb than to the first, but SADC

[5] Institutional systems are those developed for large organizations such as SADC and its River Basin Management Commissions. They are usually expected to be used for years, if not decades. Project oriented geographic information systems, on the other hand, can be more flexible when it comes to data collection. The data used in these systems is usually not expected to serve any purpose other than that specified for the project itself, and the amount of data needed is normally small when compared with that needed for an institutional GIS.

would be unwise to disregard it altogether. The Data Requirement and Availability Survey should address this issue of long–term data maintenance.

Modern GIS technology is flexible enough to allow for the economic expansion and updating of both graphic and non-graphic data. It is usually better to start the development of a geographic information system with too little data than with too much data. More and better data can always be added when it becomes available or when the need becomes obvious.

WSCU's Data Requirement and Availability Survey should address these issues and propose specific steps for upgrading and maintaining both the graphic and non-graphic elements of database.

2.3 Organizing for GIS Technology

One of the questions raised most frequently by those contemplating the use of GIS technology is "who will be responsible for managing and overseeing the use of this technology?" There is no easy answer to this question, other than "it depends on the situation." This section lays out some considerations needed to make an informed decision on this issue. Further institutional analysis at the onset of GIS work will be needed to determine a long-term capacity building strategy.

Assign a Role for GIS Technology

Before embarking on the implementation of GIS technology, management should assign it a role within the organization. This role more than anything else will determine organizational and staffing plans. A clear understanding of the role of GIS technology and agreement on that role by all participants will provide answers to many problems downstream in the implementation process. This "GIS Vision" should describe a concept of GIS use and purpose that is commonly held by all participants, as well as the understanding of individuals of the role that GIS technology will play in their work processes.

Organization and staffing plans should be drafted in response to the answers given to the following questions—not to the question "what GIS positions do we need?"

- What short term and long term role will GIS technology play within SADC, WSCU, and the River Basin Management Commissions (RBMCs)?
- Who will actually be using this technology?
- What development tasks must be accomplished to implement the technology?
- What are SADC's, WSCU's and the RBMC's long term operational goals?
- Which functions and systems do SADC, WSCU, and the RBMCs want to integrate with GIS technology?

Other factors involved in developing appropriate organizational and staffing plans for a GIS undertaking include the number of users, applications and participants; the size and extent of the system; the characteristics of the applications; and the data characteristics, volumes, types and uses. Feasibility studies can help clarify these issues.

A Permanent Fixture or a Simple Tool?

In defining the role that GIS technology will play in supporting water management in the region, SADC, WSCU and the RBMCs must also consider whether GIS technology will become a permanent part of some organization, or just provide capabilities that are limited in time and scope. The staffing responses to each of these situations will be quite different.

Assuming that an appropriate "home" for GIS capabilities can be identified, long-term program and operational needs call for the design of an organizational structure and functions that integrate into the workflow of the organization. Achieving such a permanent organizational design may take years and is a multi-step process.

GIS undertakings that are limited in scope or time may require a separate GIS staff that has its own organizational identity. This GIS unit may consist of only a project manager and associated consulting services. If GIS needs are very limited and apply to only one area, it may be preferable to integrate the GIS skills into existing professional positions. In this situation GIS may "disappear" into the organization and become no more significant than the modeling software regularly employed by the professionals. In other words, GIS technology will become just another tool in the professional's toolbox and there will be no GIS staff.[6] The more likely scenario in the SADC network is that some permanent GIS capability is to be established, preferably building on existing organizations.

Coordination and Communication

GIS organizational plans must facilitate a multi-participant environment. Successful GIS organizational strategies are those that address coordination and communication realistically and effectively. The coordination of multiple users working at the same organizational level, such as the individual RBMCs, is a major challenge that must be faced and mastered. In facing this challenge, the WSCU must address two issues—the varied interests of the individual RBMCs and the fact that it will be called upon to balance the interests of many organizations that are coequal.

Each participant will bring varied interests, application needs, data needs, priorities, organizational issues and political interests to this undertaking. Strategies will be needed to provide the means by which these varied interests can be identified and addressed, and the necessary compromises developed.

Lateral communication and coordination within a bureaucracy such as SADC is not a new issue. Many organizations have successfully tackled this problem to accomplish joint projects. The introduction of GIS technology can further complicate the issue because the data and the

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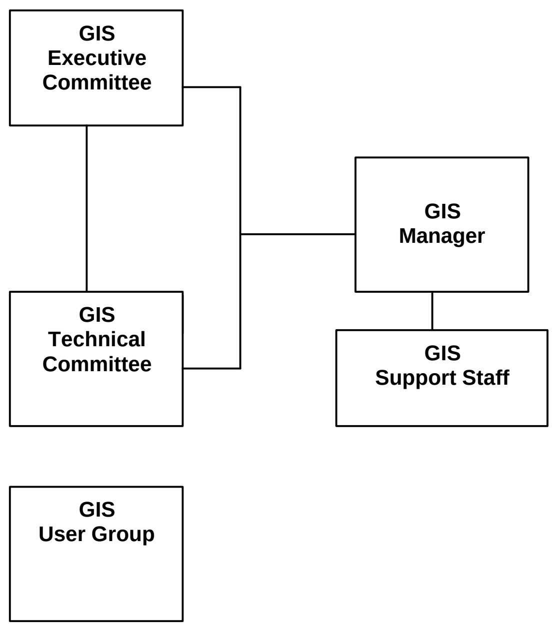
[6] Somers, Rebecca. "Management Strategies: GIS Staffing and Personnel," *GeoInfo Systems*, Vol. 4, No. 4, April 1994. Eugene, Oregon: Advanstar Communications, pp.2-4.

processes involved are interwoven throughout the organization. In WSCU's case the matter is further complicated because coordination between and among shared river basins will require coordination and cooperation among sovereign nations.

Over the past two decades some common approaches for handling multi-participant GIS programs have been developed. From among these approaches the basic model depicted in Figure 1 seems to have met with the greatest acceptance, and by implication led to the greatest success.

The Executive or Steering Committee provides policy guidance and support to the GIS effort. Typically, this committee consists of the heads of major participants. The Executive Committee approves design, development plans and funding. It also addresses any conflicts not resolved by the Technical Committee. In WSCU's case the heads of the River Basin Management Commissions and the WSCU might constitute this committee.

Figure 1. GIS Coordination and Communication [7]



The Technical Committee provides the driving force for the actual design and development of the geographic information system. In the WSCU's case members might be mid to senior level technical representatives from the River Basin Management Commissions and the WSCU. This committee should be of a workable size (6 to 8 members) so that it can function as a working group facilitating the development of the system. It should be heavily involved in the Needs Analysis and the functional design of the system. The Technical Committee discusses details and reaches compromises and refers its recommendations to the Executive (Steering) Committee for approval.

[7] Somers, Rebecca. "GIS Organization and Staffing," 1994 URISA Proceedings, Washington, D. C., p.43–45.

During the development phase, the User Group can be a valuable source for outreach to the future user community on matters such as system requirement analysis and GIS communication and education. It is most relevant once the GIS becomes operational, at which time it provides an open forum for users to meet and discuss experiences.

The GIS Manager coordinates all of these groups and drives the GIS development and operational efforts. Typically, the GIS Manager chairs the Technical Committee. Depending on the level and organizational placement of the GIS Manager, he may also chair the Executive Committee. A GIS Support Staff reports directly to the GIS Manager.

Placement within the Organization

The placement of the GIS management team within the organization can be an important factor in the success or failure of a GIS program. The management of the GIS program can be placed in one of three areas—in a line organization, in a support activity or at the executive level.

Placement in a line organization would involve positioning GIS management and staff within an operating unit such as a River Basin Management Commission. The advantage of this placement, and indeed the reason that many geographic information systems start in such a location, include the obvious tying of the geographic information system to operational need and budget. However, if the geographic information system is to serve multiple users, e.g. all activities within the Water Sector, such a location can be a disadvantage in terms of coordination, lack of inherent authority, lack of visibility and possibly a weak budget position.

GIS management could be placed in a support unit such as Information Systems or Data Processing, Technology Support or Management Support. The advantages of such placement include the institutionalization of GIS technology within an existing systems environment. This provides a professional and objective image for the geographic information system and its personnel. This location can also protect the operations and budget for the geographic information system while it is in the development stages. Disadvantages include the perception that the GIS staff is too far removed from operational needs, a potentially weak budget position and difficulties in later integrating GIS technology into the operational units of the organization.

Placement at the executive level involves the GIS manager reporting to one of the top decision-makers in the organization, such as the head of SADC or WSCU. Advantages of such placement include high visibility, inherent authority when dealing with coordination and communication matters, top executive support and perhaps a strong budget position. Disadvantages may include a perception on the part of the end users that GIS management is too far removed from their operational concerns and needs. Moreover, the high visibility may prove to be a weak point in terms of top management support and budget in a highly political atmosphere.

Historically many GIS projects began in a line department because of the inherent advantages of being tied directly to an operational need and a budget line item. This approach also allowed the manager who recognized the need for a geographic information system to provide direct support and maintain direct control of this fledgling activity. Unfortunately, as these projects expanded to serve other departments, coordination difficulties usually arose.

In recognition of the multi-participant nature of GIS technology, and the need for better coordination and funding mechanisms, more recently GIS programs have started at the executive or support level. In spite of high level support, a number of these undertakings have stalled due to complications in coordination and funding, coupled with the line users' perception that the geographic information system was not being developed in accordance with their needs. In some instances, the displeasure and impatience of the end users led them to initiate independent GIS activities.

Another danger of placement of GIS management at the executive level is that the GIS staff may seek to become a department in their own right. This, in turn, can lead to extensive duplication of effort within the organization, particularly between the GIS Department and the Information Systems Department. [8]

A Possible GIS Organizational Plan for WSCU

While the organizational concepts outlined above are based on successful experiences, this does not mean that they can or should be adopted as is, or that the WSCU can or should seek to adopt another organization's plan for GIS placement and management. The WSCU has its unique strengths and weaknesses. It is controlled by a unique set of rules and, for the most part, has to make do with available staff. In the WSCU's case, the shortage of personnel experienced in the management and use of GIS technology more than anything else may determine where to initiate GIS activity.

Having said this, WSCU may want to start building its GIS organizational infrastructure as follows:

1. Organize a GIS Executive (Steering) Committee whose members are the heads or deputy heads of the River Basin Management Commissions and the head or deputy head of the WSCU.

2. Organize a GIS Technical Committee composed of mid and senior staff members experienced with GIS technology from among those RBMCs that have already started using GIS technology.

3. Appoint a GIS Manager to manage the WSCU's implementation of GIS technology. The GIS Manager should report directly to the head of the WSCU and should have sufficient rank and credibility to deal easily with the senior staffs of both the WSCU and the RBMCs. He or she should chair the GIS Technical Committee.

4. Assign responsibility for the initial implementation of GIS technology for river basin boundary mapping to the most advanced GIS activity from among those RBMCs already using GIS technology.

5. Provide GIS training to water resource management professionals rather than seeking to train GIS specialists in the intricacies of water resource management.

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[8] Somers, Rebecca. "GIS in Local Government: Where Do You Place the GIS?" GIS World, Vol. 3, No. 2, April/May 1990. Fort Collins, CO: GIS World, Inc., pp. 38–41.

WSCU should not consider:

- Assigning responsibility for its GIS activities to a National Mapping Authority (NMA) or an existing "mapping department." A NMA or a mapping department can be used as a contractor for data conversion and Geobase development. Neither should be placed in the position of controlling WSCU's GIS activities, nor should they be given primary responsibility for river basin boundary mapping.

- Establishing a stand alone GIS Department as part of the WSCU staff. If WSCU's information systems staff is capable, it could be tasked to support the GIS Manager by providing consulting services to the GIS activities within the RBMCs.

3. SADC, the WSCU and GIS Technology

3.1 Previous Experience

The concept of using a GIS for natural resource management is not foreign to SADC. ELMS has started work on an Environmental Information System (EIS) based on the use of GIS technology and has assigned responsibility for coordinating, standardizing and distributing the spatial data developed as part of the EIS to SADC's Technical Unit (SETU) located in the Food and Security Unit in Harare, Zimbabwe.

The Zambezi River Authority has introduced the use of GIS technology to its operations, and the Japanese International Cooperation Agency (JICA) is funding the development of a geographic information system for some 120,000 square kilometers of Angola's coastal region. Botswana's National Conservation Strategy Agency (NCSA) has been designated the focal point for spatial data management for the Okavango River. Partially as a result of these many diverse and uncoordinated activities, SADC has established a Water Sector Coordination Unit (WSCU) and charged it with the responsibility for coordinating all activities of the Water Sector to include those of the River Basin Management Commissions.

Although each SADC member state has already designated a focal point for spatial data coordination within its boundaries, the potential for conflict and duplication in the development of a geographic information system for the RBMCs is already evident.

Before proceeding further, the appropriate SADC entity should convene a meeting of national GIS focal points and assist them in establishing a transnational GIS coordinating mechanism charged with oversight of the development of GIS programs and standards for SADC. This coordinating group may want to designate WSCU as the SADC entity responsible for all GIS activities relating to the development of water resource management applications and water feature data collection and maintenance. In this capacity WSCU would be the logical entity to assume responsibility for the preparation of the Needs Analysis and the Data Requirement and Availability Survey for the River Basin Management GIS Program.

3.2 WSCU and GIS Program Implementation

All involved with the creation of a geographic information system for WSCU and the River Basin Management Commissions should understand that they are embarking on a major GIS undertaking. It should not be undertaken lightly.

All involved should also understand that there is no such thing as a generic geographic information system. An organization such as WSCU cannot "buy" a geographic information system; it must develop its own. On the other hand, the steps required for the development of a geographic information are rather generic in that they are essentially those traditionally used for the development of sizeable computerized information management systems.

The following paragraphs describe the steps that WSCU and the RBMCs should take when developing their geographic information system. The more they adhere to these steps, the more successful and less costly will be their undertaking.

Phase I: Project Planning

- *Establish a Program Management Team.* A management team reporting to SADC or WSCU and containing representatives from each of the RBMCs should oversee the development of the RBMC Needs Analysis. This management team should approve the completed Needs Analysis and enforce its recommendations throughout the Sector. It should develop, promulgate and enforce spatial data standards for at least the RBMCs and, if possible, the entire Water Sector. Successful completion of this task may require the services of an experienced consultant; however, establishment of a management team is primarily and more appropriately a task for the members of SADC, WSCU and the RBMCs.

- *Conduct a RBM–GIS Needs Analysis.* This analysis should not be limited to the need for river basin maps. It should identify all of the applications that the River Basin Management (RBM) spatial database will have to support, identify the data (type and quality) that will be required for those applications and the priorities for application development. Successful completion of this task will most likely require the services of an experienced GIS consultant. If a consultant is used, he should be given three to four months to prepare and submit a draft of the Needs Analysis. Four to six weeks should suffice for the management team's review, revision and approval of the Needs Analysis.

- *Prepare a RBM–GIS Data Requirement and Availability Survey.* Once the management team has approved the Needs Analysis, the Data Requirement and Availability Survey should be prepared. Ideally, this document will address all of the data needed to support the applications listed in the Needs Analysis. Practically, it can be completed in stages using as priorities those established in the Needs Analysis for application development. Presumably, the creation of river basin boundary maps will have a relatively high priority, ranking with the development of the core Geobase.

  This analysis should tabulate the type, quantity and quality (currency, accuracy, completeness and consistency) of data required. It should identify and evaluate sources of data immediately available, and propose possible sources of data when they are not immediately available. It should specify which existing data sources may be used and which should not. It should indicate from where needed, but currently unavailable, data will be obtained.

  This document should recommend compromises in data quality where such compromises are needed to get the system up and running quickly. In such cases it should propose a schedule for the eventual upgrading and maintenance of the compromised data. It should also assign responsibilities and set completion schedules for all data collection tasks. Finally, the document should address the issues of a common geodetic datum and a single map projection system.

Successful completion of this task will most likely require the services of an experienced consultant. If a consultant is used, s/he should be given two to three months to complete the Data Requirement and Availability Survey. An additional month should be allowed for obtaining the approval of all interested parties and making any revision necessitated by the approval process. The time needed to complete this task can be shortened somewhat if it is carried out concurrently with the Needs Analysis.

Phase II: Database Creation

Experienced spatial database contractors should be used to create Geobase for the RBM–GIS and the river basin boundary overlays. Spatial database creation is a costly and time-consuming task. The skills and tools needed for this task are not necessarily those that will be needed by SADC, WSCU and the RBMCs to use the applications for which the database is being developed.

Spatial database development contractors have refined their procedures and developed quality control mechanisms for which organizations such as SADC, WSCU and the RBMCs have neither a long-term need nor the funds to replicate. SADC, WSCU and the RBMCs should concentrate their time and resources on the development of applications and the training of personnel to use and maintain the spatial database, once the contractor completes it. The contractor must address five issues:

1. *Data Collection*. If done properly, the Data Requirement and Availability Survey will enable WSCU to specify exactly what data it expects its contractor to deliver, and contractors will be able to provide realistic cost estimates for collecting those data and preparing them for entry into the spatial database. This task may involve the purchase of new satellite imagery; the commissioning of new line maps or the development of river basin boundary overlays from line maps, satellite[9] and photographic imagery in addition to collecting available survey data, maps and photographs.

   If the Data Requirement and Availability Survey specifies exactly what data are immediately available, what data can be obtained from outside sources and what data must be created, the time for selecting a contractor should be materially shortened, and the number of inevitable "contractor misunderstandings" should be minimized.

   Even if this task is assigned to a contractor, WSCU can expect to be heavily involved in the data collection process. Many of the data sources will undoubtedly belong to or be controlled by WSCU or some other entity within SADC, and provision will have to be made for providing the contractor with access to these sources of data. SADC personnel may also be needed to resolve the conflicts in existing data that the spatial database building process invariably uncovers.

2. *Database Design*. The Needs Analysis should provide most, if not all, of the guidance required for designing the spatial database. The user's systems personnel should work hand–in–glove with the contractor on this task so that, when completed and accepted, they will

[9] As satellite imagery is likely to play a major role in the developing of river basin boundaries, Attachments I and II have been added to update readers on the status of remote sensing and satellite imaging.

understand it fully and be capable of maintaining and modifying it without having to involve the contractor.

3. *Data Preparation.* Those unfamiliar with spatial database development frequently overlook or grossly underestimate this task. Data preparation is the first step in the quality assurance process. Its purpose is to ensure that as little "garbage" as possible enters the database. One of the unanticipated benefits of GIS technology has been its unnerving ability to point out errors in data that were heretofore thought to be "clean." It is in this step that datum and map projection discrepancies are fixed and conflicts between data from different sources are resolved. The cleaner the data before being passed on to the data entry step, the less costly will be the data entry process and the balance of the database building process. Spatial database contractors have the experience and tools needed to identify and fix the many common problems found in most existing sources of spatial data. They also have the advantage of not having a proprietary interest in the data and are, therefore, more open to identifying and resolving discrepancies than are frequently those to whom the data belongs.

4. *Data Entry.* This step involves the entry of both graphic and non-graphic data. It is a tedious and routine task. Spatial database contractors have selected and optimized their equipment for this task. Many have developed proprietary software and processes for data entry and data verification. Organizations such as SADC and WCSU have nothing to be gained and everything to lose by taking on the data entry task themselves. Even if they eventually develop a data entry capability equivalent to that of the more efficient of contractors, they will have little to no use for the software tools and conversion processes developed once their conversion task is finished.

   This step could involve: digitizing of existing maps; transforming[10] coordinates to a common datum and projection; edge–matching the detail on adjacent maps; fitting line map detail (vector data) to satellite images (raster data); Linking textual elements in an existing database with graphic data elements.

5. *Quality Assurance.* Both the contractor and the WSCU should establish quality assurance programs. Only those contractors who have ongoing quality assurance programs should be considered for the spatial database creation task. WSCU should establish its own quality assurance program to assure itself that the contractor is delivering that for which it is contracted and to insure that once delivered the spatial database remains uncorrupted and up to date.

Until the Needs Analysis and the Data Requirement and Availability Survey have been completed, it is not possible to estimate the time needed for creating a Geobase and river basin boundary maps.

Phase III: Hardware, Software and Networking Specification

The Needs Analysis and the Data Requirement and Availability Survey will provide the information needed to specify the hardware, software and networking capabilities for the RBM–GIS. The software should be capable of supporting development of all proposed applications;

[10] The National Imagery and Mapping Agency (NIMA) of the United States of America distributes a software program that can be used to transform geodetic, UTM and Military Grid Reference System coordinates to and from WGS 84 for over 100 datums. The program is available at www.nima.mil/GandG/madtran/madtran.html.

hardware should have the storage capacity and speed to handle the massive amounts of data that will eventually reside in the RBM–GIS. Initial networking capabilities should satisfy anticipated organizational needs for three to four years. If WSCU already has a strong information systems department, it should not require outside assistance with this task.

Phase IV: Application Development

The Needs Analysis should have established the priorities for application development. The Data Requirement and Availability Survey should have identified the data required to support the applications. The priorities in the Needs Analysis should also govern data collection and spatial database building as well as application development.

Because the development of a geographic information system is a long–term undertaking, decision–makers and financial managers frequently lose interest in mid–stream. Experience has shown that small frequent successes (the completion of simple but useful applications) is the best way to hold their interest.

Therefore, to ensure continued high level support during implementation, WSCU should be sure to include a number of support–building applications high on its priority list, even if other more complicated applications would be the first choice of the long–term daily users of the system. While WSCU can contract with outside consultants for the development of its applications, its long–term interests would be better served by developing those applications in house. In any case consultant support for this task is beyond the scope of the proposed consultancy.

Phase V: Staff Training and Development

This TOR assumes that WSCU and RBMC eventually will have access to in-house personnel with the following experience and skills to successfully implement a GIS Program for river basin management.

- *Managers and Supervisors*: GIS programs most frequently stumble or fail for lack of strong management—not for lack of technical expertise. If necessary, WSCU should consider hiring a consultant experienced in GIS implementation to support its own internal manager until such time as the internal manager has the experience and skills required to run the project on his or her own. An eighteen to 24 month consultancy should be sufficient for this purpose.

Computer Specialists: In spite of what some of its practitioners might like us to believe, there is no magic in GIS technology. The information system skills needed to establish and maintain the hard– and software of a geographic information system are those needed for all information system operations: system administrators and analysts; database managers and programmers and graphic system specialists. Some training will of course be needed on the specific software package(s) selected for the RBM–GIS, but experienced systems personnel should have no more trouble mastering GIS software than they would any other new software.

- *Application Specialists*: These are the eventual day–to–day users of the RBM–GIS. They are the ones whose needs are detailed in the Needs Analysis. They are more likely to be planners, hydrologic engineers, water resource management specialists, climatologists, cartographers, geologists, etc. than they are computer professionals. They may or may not be computer literate. If they are not, they should be given some basic computer training before being introduced to GIS technology. However, they need not become computer gurus or GIS experts. Their initial assignment is to explain what it is they expect the RBM–GIS to do for them. Their interim assignment is to ensure that the system and GIS gurus give them what they need. Long–term, it is their task to use the RBM–GIS as a tool for accomplishing their own professional assignments more efficiently and cost effectively.

- *Spatial Database Developers*: These are the people charged with building the spatial database. Their task is finite and of limited duration—collecting the data needed and entering it into the spatial database. This is a tedious and time consuming task lending itself to economies of scale, the creation of specialized procedures and the development of software tools for efficient and cost effective data conversion. Rather than trying to develop these skills among its own personnel, WSCU would be far better served by contracting this task to an experienced data conversion contractor and closely monitoring its performance.

The design and development of a comprehensive geographic information system for the WSCU and the RBMCs may initially spread SADC's current limited pool of skilled personnel rather thin. Fortunately for all, SADC has already exhibited an awareness of and commitment to the development of GIS training programs within its EIS Training and Education Sub–Program. This latter program has as its focal point the University of Botswana. SADC has also established a GIS training and research network within the appropriate departments at the universities of Dar es–Salam, Lesotho, Malawi, Namibia, Swaziland, Veda, Zambia and Zimbabwe.

The Geography Department at the University of Botswana has had an established GIS training and research curriculum for a number of years. It should be a ready source of the GIS specialists who will be needed to develop and maintain the RBMCs' geographic information systems. An additional source of trained GIS personnel may be the University of Dar es–Salam, as it offers a GIS program in cooperation with the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands.

4. Water Resource Databases for SADC

4.1 Development and Objectives of the Database

Since 1992, the Aquaculture for Local Communities Development Program (ALCOM), a regional, community-based program executed by the FAO, has been gathering information on surface water bodies from all countries in the SADC Region. This work has evolved into the establishment of a Water Resource Database (WRD) which holds a wealth of data on surface water resources in mainland SADC. The WRD is integrated in a GIS but can also be used as a stand alone application. It is composed of several separate databases that are interlinked through unique identifiers. These databases consist again of separate database files to ensure flexibility and multiple use of the same data.

Four different data types can be accessed: regular cell data, geographical data (digital map components), graphical data (figures, pictures and drawings) and descriptive documents. Some data are typically linked to water such as hydrological data, physico-chemical data, aquatic species data and fisheries data, but the database holds much more information than just narrow water issues. Administrative data on water, related socio-economic data, climatological data, topographical data, institutional data and even demographic data are included and linked to the overall database.

The linking of these types of data in a single database makes it possible to approach water management in a holistic way. The link between water availability and population density at a district or even ward level is one of the multiple examples of these uses. Determining rainfall data in a particular dam watershed to monitor filling up of the dam is another such example. What fish species do I use to stock this dam? A question that can be answered by querying for the available fish species and determining the most suitable one based on the climatological conditions. The WRD has an answer for many types of question.

4.2 Application of the Database as a Decision Support Tool

Modules are being developed in the database to allow the database to function as a decision support tool for policy-makers, government services and non-governmental organizations. Applications are numerous:

- Hydrology

    - Planning of new dams by overlay of demographic maps and water availability.

    - Monitoring of filling and drying of dams by overlay of rainfall, land use and catchment area.

- Health
  - ➢ Monitoring of waterborne diseases such as bilharzia or malaria by distribution mapping and climatology.
- Fisheries and aquaculture
  - ➢ Choice of the right species to stock by overlay of species distribution maps and climatological maps.
  - ➢ Determination of fisheries potential by modeling physico-chemistry on climatological maps.
- Irrigation
  - ➢ Analysis of potential for irrigation by overlay of water availability and water demand.
- Environment and ecology
  - ➢ Monitoring of aquatic pests and aquatic exotics by modeling migration.
  - ➢ Wildlife management by digital distribution mapping.
- General Development and food security

4.3 Main Components of the Water Resource Database

The level at which data are collected can distinguish the following components:

- Surface water body data (reservoirs, lakes, swamps with surfaces bigger than 1 ha).
- Watershed data (at the level of the sub-watershed or app. 5000 km2).
- River data (limited mainly to coverages at 1:1,000,000).
- Administrative level data: country, province, district, ward, community ...
- Aquatic species data (distribution range, occurrence, abundance, production, biology...).
- Aquatic mailing list of institutions involved in water and fisheries in SADC.
- Fishing gear data (all characteristics).
- Bibliographic data with regard to fisheries and water in SADC.

Most of the data are geo-referenced which allows immediate mapping or querying for data on geographical locations from a map. Administrative, hydrological, land use and transport maps are available in digital format for each SADC country and can be overlaid with other data from the water resource database.

Four main software components are use in the WRD interface:

- regular database program for querying and analyzing database files
- mapping program for querying and plotting data from and to maps (Windisp3, Mapviewer)
- library catalogue software for searching bibliographic references (CDS/ISIS)
- html browser for browsing hypertext documentation and displaying graphics

4.4 Sources of Data

Since the database includes data from different disciplines and different countries, the data had to be sourced equally from a multitude of governmental and non-governmental organizations. Data were compiled from:

- Existing databases (international and national).
- Published literature.
- Hardcopy and digital maps.
- Informal information and grey literature.
- Field work.

A meta-database contains the data sources for each individual entry so that those sources can be retraced easily and contacted for verification or supplementary information. In this way, the database contains also a number of useful human resources (mailing lists) which are classified by their respective disciplines.

4.5 Status and Future of the Water Resource Database

The WRD is still growing and has not yet reached it's full potential. Parts of it, such as the Surface Water Body database and the Watershed database, are already well developed while other parts such as the species distribution database, the fishing gear database and the socio-economic databases are still being established.

Major work has been achieved in standardization of identifiers for water bodies, watersheds and many other components of the databases. This was an imperative to enable linkage of all data from different sources. Efforts are being made to make the use of these identifiers more widespread to enable linkage to more external data. This will open up the WRD to programs that are active in many different disciplines such as health, dam construction or general environment. It also stresses the importance of an official and permanent home for the WRD in a leading regional institution to avoid the loss of this standardization.

Most decision support modules are still under development although other regional and national programs in decision support already use the data. Current development focuses on simple tools that can be implemented without highly skilled labor and without heavy soft-and hardware requirements.

A crucial question with regard to the future of the WRD remains the choice of the hosting institution. To date, ALCOM has been working under the SADC umbrella but without being integrated formally in a SADC structure. This integration is however critical for the longevity of the WRD, not only for it's development and updating but also for it's access and use.

With regard to the multi-disciplinary aspects and the holistic approach of the WRD, it is important to find a host that can fully realize the potential of a database that holds information on the most important resource in the SADC region—water.

4.6 SADC Watershed Model and Database

The SADC Digital Watershed Model is a joint project between ALCOM and WWF Zimbabwe. The model was derived from the 30-arc second digital elevation model (DEM) of Africa.[11] The original purpose of the model was the development of digital species distribution maps and hydrological monitoring, but ultimate applications reach far beyond this. The complete watershed model is available for downloading with attribute data in dBase format and polygons in BNA format.

Development of the Watershed Model and Naming

The delineation of the sub-basins was done based on a DEM and the DCW river layer (digitized from the ONC's) in Arc Info by a consultant. Approximately 1,100 sub-basins were delineated for subequatorial Africa. After the delineation, naming and determination of each downstream basin was done manually based on the DCW drainage and topographical layer by ALCOM.

[11] U.S and other international cooperators at the USGS EROS Data Center in Sioux Falls, South Dakota Falls, USA, had developed the DEM of Africa used. This DEM was based primarily on elevation data taken from the Digital Chart of the World (DCW) which had been digitized from the 1:1,000,000 Operational Navigation Charts (ONC) by the Environmental Systems Research Institute (ESRI) for the U.S. Defense Mapping Agency (DM—now NIMA. Where incomplete elevation data were indicated on the ONC Charts courser resolution data from the DTED DEM, also from the DMA, were used to fill elevation gaps in the USGS DEM. The interpolated resolution of the DEM of Africa corresponds to 0.0084 decimal degrees, which equates to roughly one square kilometer pixels. The DEM provided by the FAO/FSTAU to ALCOM for the project was in IDRISI format.

Classification system of the watersheds

ALCOM developed a classification system that allows determining the following within seconds and without the use of proper GIS software for each individual watershed:

- the mega-basin to which the watershed belongs (e.g. Ruvuma basin)
- all downstream basins (e.g. Zambezi from source to the ocean)
- all upstream basins or part of a mega-basin (e.g.Vaal catchment)
- the name of primary and secondary rivers in the watershed (e.g. Vaal catchment)

The basis of this classification system is a database that holds names and the identifier of the downstream basin for each sub-watershed. A list of database fields is available from ALCOM.

Use of the Watershed Model and Database

With the help of the classification system, the mapping of downstream basins, upstream basins, mega-watersheds or parts of watersheds becomes very easy. After the query, a macro button in the database allows export of a simple worksheet file that holds the ID's of the watersheds together with the most relevant data such as names and color codes. This sheet is then loaded into a relatively inexpensive mapping program (Mapviewer) which visualizes automatically the query through a hatch map with predefined colors. A small custom-written program allows extraction of the selected basins from the complete basin-file (in BNA format). Alternatively, Windisp3, a freely available mapping and simple GIS program, can be used for visualization and geographical analysis of the watershed delineation.

A poster with all the sub-watersheds in subequatorial Africa and their primary names is available at ALCOM and WWF. A simplified version with the main watersheds in Southern Africa is available as a GIF file.

Climatological, elevation and surface statistics are available for each sub-watershed that allows for quick calculation of statistics for complete mega-basins, sub-basins or individual sub-watersheds. Elevation drops over the course of a river can also easily be visualized.

The watershed model and database is currently being used to develop aquatic species distribution maps based on point locations. Monitoring of downstream spread of aquatic pests such as Water Hyacinth is equally one of the applications. Other programs are already using the data for flow analysis to monitor filling of dams based on the rainfall in the catchment area. Applications of the model however will go far beyond this, and the database is also extremely useful for educational purposes.

For additional information contact:

The Fisheries Officer, ALCOM Mail: PO Box 3730, Harare, Zimbabwe Location: Fisheries Research Unit, National Parks Complex, Sandringham Drive, Harare, Zimbabwe Telephone:

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5. River Basin Boundary Mapping: Two Approaches

This TOR provides information intended to help those charged with understanding and selecting between two specific approaches for accomplishing the production of shared river basin boundary maps for use in the geographic information system (GIS) for the SADC Water Sector Coordination Unit (WSCU).

The first approach, *Boundary Determination as an Integral Part of a GIS Program*, envisions the production of the shared basin boundary maps as but one step in the development of a geographic information system for WSCU and the River Basin Management Commissions (RBMCs).

The second, *Boundary Determination as an Independent Mapping Task*, treats the production of the shared basin boundary maps as an independent task; that is, one not linked to the development of the RBM–GIS.

If SADC intends to undertake the development of a geographic information system for WSCU and the RBMCs within the next several years, the first approach would be better. This approach should help WSCU avoid any duplication of effort and will ensure that the Geobase, the shared river basin boundaries and any proposed applications fit together seamlessly.

The second approach is a stop gap measure intended to get boundary maps into the hands of SADC water resource managers as quickly as possible without great regard for their long-term suitability for use in the RBM–GIS. The products produced using this approach may not have long-term utility, once work begins on a geographic information system.

5.1 Approach 1: Boundary Determination as an Integral Part of a GIS Program

This approach calls for the creation of the shared river basin boundary maps as an integral part of a long–term strategy for developing a River Basin Management Geographic Information System.

While requiring an extended start-up period, a seemingly large initial budget and a more skilled staff at the outset, this approach will eventually provide WSCU and the RBMCs with a comprehensive RBM–GIS at a lower overall cost and with fewer headaches than will the approach described in Section 5.2.

The steps required for this approach are:

1. Establish a GIS Executive (Steering) Committee and assign it responsibility for appointing a program manager for the development of the RBM–GIS.

2. Complete a RBM Needs Analysis.

3. Prepare a RBM Data Requirement and Availability Survey.

4. Using the foregoing documents, contract for the design and production of a spatial database meeting the immediate application requirements of the WSCU and RBMCs. The production of river basin boundary maps should be included in this step. The process used for basin boundary production itself would be essentially that outlined in the alternative approach. (See following section captioned "Boundary Determination as a Simple Mapping Task.") If the WSCU opts for boundary determination as an integral part of a GIS program, it can be sure that the basin boundaries will fit the Geobase and the national and international boundaries and will have a level of built in "intelligence" making them more adaptable for use in the RBMCs' GIS applications.

5. Concurrent with the production of the spatial database, develop those high priority applications which can be used to demonstrate the eventual usefulness of the RBM–GIS and the accuracy of the river basin boundaries. Demonstration of these applications should serve to maintain political and financial support for further development of the RBM–GIS.

6. Conduct a workshop at which the proposed river basin boundaries are presented for acceptance.

The key to gaining acceptance of the river basin boundaries produced by either approach will depend upon two factors:

- The degree of confidence that the decision-makers have in the process used to produce them.

- The perceived quality of the source material used in the production process.

Experience suggests that decision-makers will approve basin boundaries produced as part of the development of a geographic information system more readily than they will approve those produced as part of a simple mapping program. This may be so because the GIS can be used to demonstrate how well the boundaries fit the local terrain, the basin hydrology and local political and administrative boundaries.

5.2 Approach 2: Boundary Determination as a Simple Mapping Task

The river basin boundary-mapping task can be accomplished without resort to advanced technology. The steps for this approach are simple and straightforward.

1. Determine the accuracy needed in the river basin boundary–maps. (1:250,000-scale mapping should be adequate for most areas; 1: 100,000-scale mapping may be needed in more level regions.)

2. Collect the best available source material, and evaluate it for currency, completeness and suitability. (Satellite imagery is likely to be more up-to-date and geometrically accurate than many of the line maps currently available.)

3. Commission the production of new line maps, aerial photography and satellite imagery, where existing source material is deemed inadequate.

4. Locate and mark the high points along the topographic ridges depicted on the source material and use these points to draw the corresponding ridgelines.

5. Develop and draft river basin boundaries from an analysis of these ridgelines and the river and stream courses depicted on the source material. (The drafting can be done manually or with a CAD system.)

6. Edge–match the basin boundaries between adjacent draft overlays. (This should be easier to do with a CAD system than manually.)

7. Produce the proposed basin boundary overlays, fitted to the source materials used for the ridgeline analysis.

8. Conduct a workshop at which the proposed river basin boundaries are presented for consideration and acceptance.

This approach has the advantage of costing less initially and of not requiring a highly skilled staff. It requires virtually no technology, unless the decision is made to use a CAD system for drafting. A staff of skilled draftspersons, several knowledgeable and experienced first line supervisors and a strong production manager should be able to complete the task satisfactorily.

Once the river basin boundaries have been approved, they can be digitized (if not produced in a CAD system) and fitted to the Geobase of WSCU's geographic information system—whenever such a system is ready for them. The degree to which the boundary maps will fit the Geobase will depend upon the degree to which they were created from sources based on the same geodetic datum and the same system of coordinate projection.

6. Detailed Terms of Reference

This section presents three Terms of Reference (TOR). The TOR at paragraph 6.1 is based on the approach outlined in Section 5.1. The TOR at Section 6.2 is based on the approach discussed in Section 5.2.

The TOR at Section 6.3 has been prepared in respond to a request made at the 12 May 99 meeting of the SADC Water Resources Technical Committee in Angola. This approach allows boundary mapping to proceed while the WSCU investigates the feasibility of adopting a region-wide GIS approach to boundary mapping and river basin management at some future date . It combines and expands upon elements of the approaches outlined in Sections 5.1 and 5.2.

6.1 Approach 1: GIS Approach

Background

A relative scarcity of water, high evaporation rates throughout much of the region and an ever-increasing population have prompted SADC to develop a Water Protocol to regulate the use of the region's shared water resources. This Protocol mandates the creation of a River Basin Management Commission (RBMC) for each of the shared watercourses. These RBMCs are to be responsible for "collecting, storing, retrieving, disseminating, exchanging, analyzing and utilizing data relevant to the integrated development of the resources within the shared water course systems."

Until August 1996 SADC's Environment and Land Management Sector (ELMS), based in Maseru, was charged with coordinating the activities of the RBMCs. At that time SADC established a Water Sector Coordination Unit (WSCU) and charged it with the responsibility for coordinating all activities within the Water Sector including those of the RBMCs.

To accomplish their missions the WSCU and the RBMCs need better tools. Among the tools proposed for design and development is a comprehensive geographic information system to support water resources management throughout the SADC region. Among the data to be contained within that GIS is a set of river basin maps delineating the boundaries of all shared river basins within the region. (In practice, all basins within SADC member countries—shared or otherwise—eventually will need to be delineated). When completed, these boundary maps must be sufficiently accurate to obtain the approval and acceptance of all SADC member states.

Activity Objective

The objective of this activity is the mapping of shared river basin boundaries within the SADC region and the acceptance of those boundaries by all SADC member states. SADC desires that this be done in such a way that the agreed upon boundaries can be used in a geographic information system capable of supporting the immediate and long-term needs of the WSCU and the individual RBMCs.

Specific Objectives

The specific objectives of these Terms of Reference are to:

1. Assist WSCU with the development of a Steering Committee for managing the development of a geographic information system suitable for the **long–term** needs of WSCU and the RBMCs.

2. Assist WSCU with the preparation of a Needs Analysis supporting the development of a geographic information system suitable for the **long–term** needs of WSCU and the RBMCs.

3. Assist WSCU with the development of a Data Requirement and Availability Survey supporting the development of a geographic information system suitable for the **long–term** needs of WSCU and the RBMCs.

4. Assist WSCU with the development of technical specifications for contracting designing and building of a spatial database <u>including the production of river basin boundary maps</u> suitable for supporting the **immediate** needs of WSCU and the RBMCs.

5. Assist WSCU with the oversight of the spatial database and river basin map production contractor.

6. Assist WSCU with obtaining SADC member support for the completed river basin maps.

TASK 1 GIS Executive (Steering) Committee Development

- Objective: To organize and oriente a Steering Committee whose responsibilities shall be the oversight of all GIS projects within SADC's Water Sector to include but not be limited to the development of a geographic information system capable of supporting the long-term needs of all River Basin Management Commissions.

- Input:

  - In coordination with the staff of the WSCU, survey the Water Sector for the purpose of documenting all GIS projects and programs currently underway or proposed for implementation within the next two years.

  - Assist SADC and the staff of the WSCU, with the organizing and orienting of a GIS Executive (Steering) Committee charged with overseeing all GIS activity within the Water Sector.

- Expected Outcomes:

  - A catalogue of all current or proposed GIS activities within the Water Sector.

  - By the completion of the River Basin Management spatial database, a Steering Committee that is actively overseeing all GIS projects and programs within the Water Sector.

TASK 2 Needs Analysis Preparation

- *Objective*: To develop, in cooperation with the WSCU, a comprehensive Needs Analysis suitable for guiding the development of geographic information systems throughout the Water Sector for five years. Said Needs Analysis should specify and prioritize the development of all GIS applications needed for water resource and river basin management within the next five years.

- Input:

  - Prepare, in coordination with the WSCU, a Needs Analysis suitable for guiding the development of geographic information systems throughout the Water Sector for the next five years.

  - Plan, organize and facilitate a workshop designed to gain approval of the Needs Analysis.

- *Expected Outcome*: Approval and acceptance of a Needs Analysis suitable for guiding the development of geographic information systems throughout the Water Sector.

TASK 3 Data Requirement and Availability Survey Preparation

- *Objective*: To develop, in cooperation with the WSCU, a Data Requirement and Availability Survey suitable for supporting the development of GIS applications throughout the Water Sector for the next five years. Said Data Requirement and Availability Survey should specify and prioritize all data collection and new data production requirements needed to support the development of the priority applications listed in the Needs Analysis.

- *Input*:

  - Prepare, in coordination with the WSCU, a Data Requirement and Availability Survey suitable for supporting the development of GIS applications throughout the Water Sector for five years.

  - Plan, organize and facilitate a workshop designed to gain approval of the Data Requirement and Availability Survey.

- *Expected Outcome*: Approval and acceptance of a Data Requirement and Availability Survey suitable for support the development of GIS applications throughout the Water Sector.

TASK 4 Technical Specification Preparation

- *Objective*: To prepare, in cooperation with the WSCU, technical specifications suitable for contracting for the design and production of a spatial database and river basin boundary maps capable of supporting high priority GIS applications throughout the Water Sector for the next five years.

  Said specifications are to be based on the Needs Analysis and Data Requirement and Availability Survey and could cover topics such as geodetic control, photographic and satellite imagery acquisition, line map production, data conversion and database design.

- *Input*:

  - Prepare, in coordination with the WSCU, technical specifications suitable for contracting for the acquisition of control surveys, aerial photography, satellite imagery, new line mapping, etc., as needed to support the construction of the RMB–GIS spatial database.

  - Develop, in coordination with the WSCU, technical specifications suitable for contracting for the design and production of a spatial database and river basin boundary maps sufficient for supporting the development of the priority applications listed in the Needs Analysis.

    At a minimum the spatial database should include graphic and non-graphic data describing: primary and secondary political and administrative boundaries; boundaries for all shared river basins; contours and spot elevations; water features in sufficient detail to accurately represent the pattern of drainage within each shared river basin and throughout the region; primary and secondary roads; major features related to water resource management and distribution (dams, canals, etc.); and any other features specified in the Needs Analysis as being necessary for high priority application development.

- *Expected Outcome*: Technical specifications suitable for contracting for all phases of spatial database and river basin map production.

TASK 5 Oversight of Database Production

- *Objective*: To develop and document, in cooperation with the Steering Committee, a Quality Assurance Program suitable for monitoring the performance of the spatial database contractor and to assist the WSCU staff with the monitoring task.

- Input:

  - Develop, in coordination with the Steering Committee, a Quality Assurance Program for monitoring the performance of the spatial data contractor.

  - Train the WSCU staff in the implementation of the Quality Assurance Program.

- Conduct periodic inspections of the work of the spatial database contractor and periodic reviews of the performance of the WSCU quality assurance staff.

- *Expected Outcomes*:

  - A documented Quality Assurance Program successfully implemented by the WSCU staff.

  - A spatial database and river basin boundary maps suitable for supporting the development of all high priority applications listed in the Needs Analysis.

TASK 6 Gaining Acceptance for the River Basin Boundary Maps

➢ Objective: To obtain member state approval and acceptance of a set of river basin boundary maps for the shared river basins within SADC.

➢ Input:

- Develop a marketing program that the WSCU staff can use to elicit support for approval of the river basin boundary maps from all appropriate authorities within SADC.

- Plan, organize and facilitate a workshop designed to gain support for the approval of the river basin boundaries from all appropriate authorities within SADC.

➢ Expected Outcome: An approved set of shared river basin boundary maps.

Level of Effort Required

One highly qualified GIS management consultant working in cooperation with the WSCU staff will require <u>14.5 person-months plus the additional time indicated below</u> to complete the Terms of Reference. As the steps are largely sequential, more than one consultant cannot be used to accelerate completion of this the activity. The work associated with each task can be summarized as follows:

TASK *GIS Executive (Steering) Committee Development*: Four to six person-weeks will be required at the start of the project to create a directory of all current GIS activity within ELMS and WSCU and to work with WSCU staff to develop a clear understanding of the need for a GIS Executive (Steering) Committee.

The consultant should support the work of the GIS Executive (Steering) Committee until the spatial database is completed and accepted. One person-week per quarter should suffice for this purpose.

Time required—1.5 person-months <u>plus one person-week per quarter until the spatial database and river basin boundaries are completed and accepted</u>.

TASK 2 *Needs Analysis*: Assuming the need to travel to each of the 15 river basins, one person-week per commission should be sufficient for research and analysis. Three to four additional weeks should suffice for completion and presentation of the associated report.

Time required—5 person-months.

TASK 3 *Data Requirement and Availability Survey*: Assuming five person-months were allocated for Task 2, six person-weeks should be sufficient for the research phase of this task. Four weeks should suffice for completion and presentation of the associated report.

Time required—2.5 person-months.

TASK 4 *Technical Specification Preparation*: Assuming full participation of WSCU personnel in Tasks 1, 2 and 3, six to eight weeks should suffice for writing and gaining acceptance of technical specifications for the design and production of the spatial database and river basin boundary maps. *Total time required—2 person-months*.

Should specifications be needed for the acquisition of new aerial photography, new satellite imagery, new control surveys or new line map production, additional time will be required. Until the Needs Analysis and Data Requirement and Availability Survey are completed, the total magnitude of this task cannot be meaningfully estimated.[12]

TASK 5 *Oversight of Database Production*: The documentation of a Quality Assurance program for use by the WSCU staff in monitoring the performance of the spatial database contractor should take from six to eight weeks. An additional two weeks should be allocated for training the WSCU contract monitors in its use.

Time *required—2.5 person-months*.

The consultant should be allocated additional time for periodic inspections of the contractor's database production operation and his delivered products. One week per quarter over the life of the database production contractor's contract should suffice. Until the Needs Analysis and Data Requirement and Availability Survey are completed, the total magnitude of this task cannot be meaningfully estimated.

TASK 6 *Gaining Acceptance for the River Basin Boundary Maps*: Four person-weeks should be sufficient for developing a marketing program and organizing and facilitating a workshop for gaining acceptance of the river basin boundaries produced by the spatial

[12] Each 1:250,000–scale map covers approximately 15,000 square kilometers. Up to 700 maps could be required to produce the spatial database and/or river basin boundary overlays for the entire SADC region. Until one determines approximately how many maps are required to plot the boundaries of the shared river basins, any estimate for production costs will be idle speculation. Even after an approximate map count becomes available, one will need some understanding of their scale, availability, currency and accuracy before attempting to estimate the magnitude of the production task. The cost of production could vary by an order of magnitude or more, if currently available sources are such that new mapping and/or new photographic or satellite imagery is required.

database contractor. This time might not suffice if approval of the river basin boundaries requires any sort of legislative or judicial certification. This latter task, if required, should be the responsibility of the WSCU staff.

Time required—1 person-month.

Consultant Qualifications

The consultant provided to execute these tasks should have the following qualifications:

- At least 12 years of experience as a management consultant with a specialization in surveying, mapping, remote sensing and geographic information system development.

- At least 5 years of experience working in a surveying, mapping, remote sensing or GIS production organization.

- At least 5 years of experience working in developing countries.

- A demonstrable track record in assisting clients with the development of geographic information systems and/or the management, development and operation of sizeable geographic information systems.

- An education at the college level involving the study of one or more of the following disciplines: computer science with an emphasis on GIS technology, survey, mapping, organizational development or public organization management.

6.2 Approach 2: Simple Mapping Approach

Background

A relative scarcity of water, high evaporation rates throughout much of the region and an ever-increasing population have prompted SADC to develop a Water Protocol to regulate the use of the region's shared water resources. This Protocol mandates the creation of a River Basin Management Commission (RBMC) for each of the shared watercourse systems. These RBMCs are to be responsible for "collecting, storing, retrieving, disseminating, exchanging, analyzing and utilizing data relevant to the integrated development of the resources within the shared water course systems."

Until August 1996 SADC's Environment and Land Management Sector (ELMS), based in Maseru, was charged with coordinating the activities of the RBMCs. At that time SADC established a Water Sector Coordination Unit (WSCU) and charged it with the responsibility for coordinating all activities within the Water Sector including those of the RBMCs.

To accomplish their missions the WSCU and the RBMCs need better tools. Among the tools proposed for development is a set of river basin boundary maps that delineate the boundaries of all shared river basins within the region. When completed these boundary maps must be sufficiently accurate to obtain the approval and acceptance of all SADC member states.

Activity Objective

The objective of this activity is the mapping of shared river basin boundaries within the SADC region and the acceptance of those boundaries by all SADC member states.

Specific Objectives

The specific objectives are to:

1. Assist WSCU with the development of a Data Requirement and Availability Survey to support the production of river basin boundary maps for all shared river basins with SADC.

2. Assist WSCU with the development of technical specifications for contracting the production of river basin boundary maps suitable for supporting its needs and those of the River Basin Management Commissions (RBMCs).

3. Assist WSCU with the oversight of the river basin map production contractor.

4. Assist WSCU with obtaining SADC member support for the completed river basin maps.

TASK 1 Data Requirement and Availability Survey Preparation

➢ *Objective*: To develop, in cooperation with the WSCU, a Data Requirement and Availability Survey suitable for supporting the production of river basin boundary maps for all shared river basins within SADC. Said Data Requirement and Availability Survey should specify and prioritize all data collection and new data production requirements needed to support the production of the river basin boundary maps.

➢ *Input*:

- Prepare, in coordination with the WSCU, a Data Requirement and Availability Survey suitable for supporting the production of river basin boundary maps for all shared river basins.

- Plan, organize and facilitate a workshop designed to gain approval of the Data Requirement and Availability Survey.

➢ *Expected Outcome*: Approval and acceptance of a Data Requirement and Availability Survey suitable for supporting the production of river basin boundary maps for all shared river basins.

TASK 2   Technical Specification Preparation

- *Objective*: To prepare, in cooperation with the WSCU, technical specifications suitable for contracting for the production of river basin boundary maps for all shared river basins within SADC.

- Said specifications should take into account the Data Requirement and Availability Survey and could cover topics such as new geodetic control, new photographic and satellite imagery acquisition, new line map production and data conversion.

- *Input*:

    - Prepare, in coordination with the WSCU, technical specifications suitable for contracting for the acquisition of control surveys, aerial photography, satellite imagery, new line mapping, etc., as needed to support river basin map production.

    - Develop, in coordination with the WSCU, technical specifications suitable for contracting for the production of river basin boundary maps sufficient to the needs of SADC and the River Basin Management Commissions.

      At a minimum the river basin maps should be registered to basemaps or satellite imagery covering the entire SADC region and related to a common datum and a common coordinate system.

- *Expected Outcome*: Technical specifications sufficient for contracting for all phases of river basin boundary map production.

TASK 3   Oversight of Database Production

- *Objective*: To develop and document, in cooperation with the WSCU, a Quality Assurance Program suitable for monitoring the performance of the river basin boundary mapping contractor and to assist the WSCU staff with the monitoring task.

- Input:

    - Develop, in coordination with the WSCU, a Quality Assurance Program for monitoring the performance of the river basin boundary-mapping contractor.

    - Train the WSCU staff in the implementation of the Quality Assurance Program.

    - Conduct periodic inspections of the work of the river basin boundary mapping and periodic reviews of the performance of the WSCU quality assurance staff.

- *Expected Outcomes*:

    - A documented Quality Assurance Program successfully implemented by the WSCU staff.

- Accurate and complete shared river basin boundary maps.

TASK 4 Gaining Acceptance for the River Basin Boundary Maps

- Objective: To obtain member state approval and acceptance of a set of river basin boundary maps for the shared river basins within SADC.

- Input:

    - Develop a marketing program that the WSCU staff can use to elicit support for approval of the river basin boundary maps from all appropriate authorities within SADC.

    - Plan, organize and facilitate a workshop designed to gain support for the approval of the river basin boundaries from all appropriate authorities within SADC.

- Expected Outcome: An approved set of shared river basin boundary maps.

Level of Effort Required

One highly qualified GIS management consultant working in cooperation with the WSCU staff will require 6 person-months plus the additional unspecified time indicated below to complete the Terms of Reference. As the steps are largely sequential, more than one consultant cannot be used to accelerate completion of this the activity. The work associated with each task can be summarized as follows:

TASK 1 *Data Requirement and Availability Survey*: Eight to nine person-weeks should be sufficient for the research phase of this task. Four weeks should suffice for completion and presentation of the associated report.

Time required—3 person-months.

TASK 2 *Technical Specification Preparation*: Assuming full participation of WSCU personnel in Task 1 three to four weeks should suffice for writing and gaining acceptance of technical specifications for the production of the river basin boundary maps.

Time required—1 person-month.

Should specifications be needed for the acquisition of new aerial photography, new satellite imagery, new control surveys or new line map production, additional time will be required. Until the Data Requirement and Availability Survey is completed, the total magnitude of this task cannot be meaningfully estimated.[13]

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[13] Each 1:250,000–scale map covers approximately 15,000 square kilometers. Up to 700 maps could be required to produce the spatial database and/or river basin boundary overlays for the entire SADC region. Until one determines approximately how many maps are required to plot the boundaries of the shared river basins, any estimate for production costs will be idle speculation. Even after an approximate map count becomes available, one will need some understanding of their scale, availability, currency and accuracy before attempting to estimate the magnitude of the production task. The cost of production could vary by an order

TASK 3 *Oversight of Database Production*: The documentation of a Quality Assurance program for use by the WSCU staff in monitoring the performance of the river basin boundary mapping should take from two to three weeks. An additional one to two weeks should be allocated for training the WSCU contract monitors.

Time required—1 person-months.

The consultant should be allocated additional time for periodic inspections of the contractor's database production operation and his delivered products. One week per quarter over the life of the database production contractor's contract should suffice. Until the Data Requirement and Availability Survey is completed, the total magnitude of this task cannot be meaningfully estimated.

TASK 4 *Gaining Acceptance for the River Basin Boundary Maps*: Four person-weeks should be sufficient for developing a marketing program and organizing and facilitating a workshop for gaining acceptance of the river basin boundaries produced by the river basin boundary mapping contractor. This time might not suffice if approval of the river basin boundaries requires any sort of legislative or judicial certification. This latter task, if required, should be the responsibility of the WSCU staff.

Time required—1 person- month.

Consultant Qualifications

The consultant provided to execute these tasks should have the following qualifications:

- At least 10 years of experience as a management consultant with a specialization in surveying, mapping or remote sensing.
- At least 5 years of experience working in a surveying, mapping or remote sensing production organization.
- At least 5 years of experience working in developing countries.
- A demonstrable track record in assisting clients with the management of large mapping projects using digital surveying and mapping technologies.
- An education at the college level involving the study of one or more of the following disciplines: computer science with an emphasis on GIS technology, survey, mapping, organizational development or public organization management.

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of magnitude or more, if currently available sources are such that new mapping and/or new photographic or satellite imagery is required.

6.3 Approach 3: Pilot Mapping Project and GIS Feasibility Study

Background

A relative scarcity of water, high evaporation rates throughout much of the region and an ever-increasing population have prompted SADC to develop a Water Protocol to regulate the use of the region's shared water resources. This Protocol mandates the creation of a River Basin Management Commission (RBMC) for each of the shared watercourse systems. These RBMCs are to be responsible for "collecting, storing, retrieving, disseminating, exchanging, analyzing and utilizing data relevant to the integrated development of the resources within the shared water course systems."

Until August 1996 SADC's Environment and Land Management Sector (ELMS), based in Maseru, was charged with coordinating the activities of the RBMCs. At that time SADC established a Water Sector Coordination Unit (WSCU) and charged it with the responsibility for coordinating all activities within the Water Sector including those of the RBMCs.

To accomplish their missions the WSCU and the RBMCs need better tools. Among the tools proposed for development is a set of river basin boundary maps that delineate the boundaries of the selected shared river basins within the region. When completed these boundary maps should be capable of being entered into a geographic information system and must be sufficiently accurate to obtain the approval and acceptance of all SADC member states.

Activity Objectives

The objectives of this activity are to:

1. Carry out a pilot project in one or two shared river basins designed to develop technical procedures and cost estimates for the eventual mapping of the boundaries for all 15 shared river basins within the SADC region.

2. Prepare recommendations as to the feasibility of the WSCU using GIS technology as a tool for "collecting, storing, retrieving, disseminating, exchanging, analyzing and utilizing data relevant to the integrated development of the resources within [the region's] shared water course systems."

Pilot Project Objectives

The specific objectives of the pilot project are to:

- Assist the WSCU with the development of technical specifications for contracting the production of boundary maps for selected river basins within the SADC region.

- Assist the WSCU with the oversight of the river basin map production contractor.

- Assist the WSCU in documenting the mapping procedures used by the river basin mapping contractor and developing unit costs for the various mapping activities involved.

- Assist the WSCU in obtaining SADC member support for the completed river basin boundary maps and the technical procedures used to produce them.

TASK 1 Technical Specification Preparation

- *Objective*: To prepare technical specifications suitable for contracting the production of river basin boundary maps for one or two selected river basins within the SADC region. Since this is a pilot project, the selection of basins to be mapped is important. WSCU should consider selecting basins that meet the following criteria:

  - Basins should cover some part of two and no more than four countries. This will reduce the complexity of the approval task, but still allow for the testing and development of workable approval procedures.

  - Basins should be of average size. Neither the largest nor the smallest basin should be mapped during the pilot project.

  - If two basins are to be mapped, they should not be adjacent to each other and their geography should be markedly different. This will provide a greater diversity of experience on which to base future cost estimates than would the mapping of adjacent and geographically similar basins.

Technical specifications should take into account all available data sources that might be useful to the mapping contractor to include the work done on watercourse mapping by the FAO (see: http://www.zamnet.zm/zamnet/alcom/alcom.htp). The specifications should cover such topics as final map scale, geodetic datum and control, photographic and satellite imagery acquisition and ground truthing, line map production and data conversion, as necessary.

- *Input*:

  - In coordination with the WSCU staff prepare a Data Availability Survey for the selected shared river basins. Use this information as a resource for determining what new topographic mapping will be required to support the development of boundary maps for the selected shared river basins.

  - In coordination with the WSCU staff draft technical specifications suitable for contracting for the acquisition of new control surveys, aerial photography, satellite imagery, line mapping, ground truthing, etc., as needed to support boundary map production for the selected basins.

  - In coordination with the WSCU staff write technical specifications suitable for contracting for the production of river basin boundary maps of the selected shared river basins sufficient to the water course management needs of SADC and the River Basin Management Commissions. Said boundary maps should be registered to topographic basemaps or satellite imagery covering the entire basin and referenced to an agreed geodetic datum and map coordinate system.

- *Expected Outcome*: Technical specifications sufficient for contracting all necessary phases of basin boundary map production for the selected river basins.

TASK 2 Quality Assurance Program Development

- *Objective*: To develop and document, in cooperation with the WSCU staff, a Quality Assurance Program suitable for monitoring the performance of the river basin boundary mapping contractor and to assist the WSCU staff with the monitoring task.

- *Input:*

  - In coordination with the WSCU staff draw up a Quality Assurance Program for monitoring the performance of the river basin boundary-mapping contractor.

  - Train the WSCU staff in the implementation of the Quality Assurance Program.

  - Conduct periodic inspections of the work of the river basin boundary mapping contractor and periodic reviews of the performance of the WSCU quality assurance staff.

- *Expected Outcomes*:

  - A documented Quality Assurance Program successfully implemented by the WSCU staff.

  - Basin boundary maps adequate to the needs of the WSCU and the RBMCs.

TASK 3 Document Technical Procedures and Costs

- Objectives: To document the technical procedures used by the mapping contractor to map the basin boundaries and to develop unit cost factors for better estimating the cost of mapping the boundaries of other shared river basins.

- Input:

  - Work with the map production contractor to document each phase of the map production process in a form suitable for use by others when mapping other shared river basin boundaries and for obtaining approval of the production process from the appropriate SADC authorities.

  - Work with the map production contractor to collect statistical data (time and materials costs) for the different phases of the map production process for use in developing unit cost factors for mapping the boundaries of other shared river basins.

- Expected Outcomes:

- Documented technical procedures that can be used to guide and direct the production of boundary maps for other shared river basins and that can be presented to the appropriate SADC authorities for approval as part of the boundary definition approval process.

- Realistic unit cost factors that can be used to estimate the cost of mapping the boundaries of other shared river basins.

TASK 4 Gaining Acceptance for the River Basin Boundary Maps

➢ Objective: To obtain approval and acceptance of boundary definitions (river basin boundary maps) for the selected shared river basins and the technical procedures used to produce them.

➢ Input:

- Develop a marketing program that the WSCU staff can use to elicit support from appropriate SADC authorities for the approval of the boundary definitions for the selected shared river basins and the technical procedures used to produce them.

- Plan, organize and facilitate workshops and technical briefings designed to gain support for the approval of the river basin boundaries from all appropriate SADC authorities.

➢ Expected Outcome: An approved set of shared river basin boundary maps and an approved set of technical procedures for use as a guide in producing boundary maps for other shared river basins.

Level of Effort Required

One highly qualified surveying and mapping management consultant working in cooperation with the WSCU staff will require 6 person-months plus the additional unspecified time indicated below to complete the Terms of Reference. As the steps are sequential, more than one consultant cannot be used to accelerate completion of this activity; however, the Pilot Project could be carried out simultaneously with and independently of the GIS Feasibility Study. The work associated with each task of the pilot project can be summarized as follows:

TASK 1 *Technical Specification Preparation*: Assuming full participation of WSCU personnel in this task: two to three weeks will be required for documenting the current availability of data in the selected basins; two to three weeks will be required for writing technical specifications for boundary mapping; and two to three weeks will be required to obtain approval of the technical specifications.

Time required—2 person-months ***plus*** *any time required for writing technical specifications for new topographic surveying and mapping*.

Should specifications be need for the acquisition of new aerial photography, new satellite imagery, new control surveys or new topographic map production, the consultant will require additional time. Until the Data Availability Survey is completed, the total magnitude of this task cannot be meaningfully estimated.

TASK 2 *Quality Assurance Program Development*: The documentation of a Quality Assurance program for use by the WSCU staff in monitoring the performance of the river basin boundary mapping will take from two to three weeks. An additional one two weeks should be allocated for training the WSCU contract monitors.

Time required—1 person-month.

TASK 3 *Document Technical Procedures and Costs*: The consultant will require time for periodic inspections of the mapping contractor's production operation and his delivered products. Until the Technical Specifications are completed, the magnitude of this task cannot be meaningfully estimated. At least one full person-month will be required to document technical procedures and production costs

Time required—1 person-month ***plus*** *time for periodic inspection visits to the map production contractor*.

TASK 4 *Gaining Acceptance for the River Basin Boundary Maps*: Four person-weeks will be required for developing a marketing program and organizing workshops and preparing technical presentations for gaining acceptance of the boundary definitions and technical procedures developed by the mapping contractor. Two to three weeks will be required for conducting and documenting the results of the workshops and technical presentations.

Time required—1.75 months. This time will most likely not suffice if approval of the river basin boundary definitions requires any sort of legislative or judicial certification. This latter task, if required, should be the sole responsibility of the WSCU staff, not the consultant.

Consultant Qualifications

The consultant provided to execute these tasks should have the following qualifications:

- At least 10 years of experience as a management consultant with a specialization in surveying, mapping or remote sensing.

- At least 5 years of experience working in a surveying, mapping or remote sensing production organization.

- At least 5 years of experience working in developing countries.

- A demonstrable track record in assisting clients with the management of large mapping projects using digital surveying and mapping technologies.

- An education at the college level involving the study of one or more of the following disciplines: computer science with an emphasis on GIS technology, survey, mapping, organizational development or public organization management.

6.4 GIS Feasibility Study Objectives

The specific objectives of the GIS Feasibility Study are to:

- Determine the technical and economic feasibility of the WSCU using GIS technology as a tool for "collecting, storing, retrieving, disseminating, exchanging, analyzing and utilizing data relevant to the integrated development of the resources within [the region's] shared water course systems."

- Develop specific recommendations regarding the implementation of a shared river basin boundary mapping program designed to support the WSCU's use of GIS technology as a tool for shared river basin management.

- Assist the WSCU staff in obtaining SADC approval of the foregoing recommendations.

TASK 1 Organize a GIS Executive (Steering) Committee

➢ Objective: To organize and orient an Executive (Steering) Committee whose responsibilities shall be the oversight of all GIS programs within the Water Sector to include but not be limited to the development of a geographic information system capable of supporting the long-term (5 years) needs of all River Basin Management Commissions.

➢ Input:

- Assist the WSCU staff with the organizing and orienting of a GIS Executive (Steering) Committee.

- Develop and present a workshop to the members of the GIS Executive (Steering) Committee describing their role and familiarizing them with the types of issues that they will likely be asked to address during the course of the GIS Feasibility Study.

➢ Expected Outcomes:

- A one-day workshop for the members of the GIS Executive (Steering) Committee—completed.

- By the completion of the pilot project and the GIS Feasibility Study, an Executive (Steering) Committee capable of actively overseeing all GIS programs within the Water Sector" formed and functioning.

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TASK 2 Prepare a Needs Analysis

➢ *Objective*: To develop a comprehensive Needs Analysis suitable for guiding the development of a geographic information system for the Water Sector for the next five years. Said Needs

Analysis should specify and prioritize the development of all GIS applications needed for water resource and river basin management during this period.

- Input:

    - In coordination with the staff of the WSCU, survey the Water Sector for the purpose of documenting all GIS projects and programs currently underway or approved for implementation within the next two years.

    - In coordination with the staff of the WSCU prepare a Needs Analysis suitable for guiding the development of geographic information systems throughout the Water Sector for the next five years.

    - Plan, organize and facilitate a workshop designed to gain approval of the completed Needs Analysis.

- *Expected Outcome*:

    - A catalogue of all current GIS activity within the Water Sector.

    - An approved and accepted Needs Analysis to be used as the basis for the Feasibility Study.

TASK 3 Conduct a Data Availability Survey

- *Objective*: To conduct a survey of all appropriate data sources within the SADC region for the purpose of determining what data is available to support the approved Needs Analysis and what data WSCU will have to create. Said survey should:

    - Identify all data needed to support the development of GIS applications for the Water Sector for the next five years;

    - Document all data currently available and the source of those data including any suitable data available from the FAO as part its African watercourse mapping program (see: http://www.zamnet.zm/zamnet/alcom/alcom.htp); and

    - Specify and prioritize any new data production needed to support the development of the priority applications listed in the Needs Analysis.

- *Input*:

    - In coordination with the staff of the WSCU survey all appropriate data providers within the SADC region including the FAO/WWW in Harare.

    - In coordination with the staff of the WSCU document data availability and the need for new data production.

- *Expected Outcome*: A comprehensive survey of data requirements and availability suitable for supporting the development of the GIS applications listed in the approved Needs Analysis.

TASK 4 Determine Equipment and Staffing Requirements

- *Objective*: To determine the equipment, staff and training needed by the WSCU and the RBMCs to implement the GIS program envisioned in the approved Needs Analysis.

- *Input*:

    - In coordination with the staff of the WSCU determine the equipment, staff and training required to support the development of GIS applications throughout the Water Sector for the next five years.

- *Expected Outcome*: Documentation of the equipment, staffing and training required to support the development of the priority applications listed in the Needs Analysis.

TASK 5 Estimate Costs and Benefits

- *Objective*: To calculate the cost of implementing the GIS program envisioned in the Needs Analysis.

- Input:

    - Using the unit cost factors from the Pilot Project and other appropriate financial data, estimate the 5–Year cost of implementing the GIS program envisioned in the Needs Analysis.

    - Document all tangible and intangible benefits that might accrue to SADC and the WSCU from implementation of the proposed GIS program.

- *Expected Outcome*: documentation of the costs and benefits that will accrue to SADC and the WSCU from implementation of the proposed GIS program

TASK 6 Present the GIS Feasibility Study

➢ Objective: To gain acceptance of the GIS Feasibility Study and the proposed GIS program.

➢ Input:

- Complete the required GIS Feasibility study and develop presentation materials for use in gaining support for its recommendations.

- Plan, organize and facilitate a series of workshops designed to explain the findings of the GIS Feasibility and gain support for its recommendations.

- As a result of the workshops, revise the GIS Feasibility Study, as needed.

- Deliver the completed GIS Feasibility to the appropriate SADC and WSCU authorities.

➢ Expected Outcome: Approval and acceptance of the GIS Feasibility Study.

Level of Effort Required

One highly qualified GIS management consultant working in cooperation with the WSCU staff will require 11 person-months to complete the Terms of Reference. As the steps are sequential, more than one consultant cannot be used to accelerate completion of this report; however, the GIS Feasibility Study could be carried out simultaneously with and independently of the Pilot Project. The work associated with each task can be summarized as follows:

TASK 1 *Organize a GIS Executive (Steering) Committee*: Three person-weeks should be allotted for this task at the start of the project. One additional week to be used throughout the life of the study should also be allocated for this task

Time required—1 person-month.

TASK 2 *Prepare A Needs Analysis*: Assuming the need to travel to each of the 15 river basins, one person-week per RBMC should be sufficient for research. Five additional weeks should be allocated for completion and presentation of the Needs Analysis.

Time required—5 person-months.

TASK 3 *Conduct A Data Availability Survey*: Assuming that five person-months were allocated for Task 2, six person-weeks should be sufficient for the research. Two additional weeks should suffice for full documentation of the survey.

Time required—2 person-months.

TASK 4 *Determine Equipment and Personnel Requirements*: Two person-weeks should be sufficient for documenting current GIS equipment, staffing and training conditions throughout the WSCU and RBMCs. Two additional weeks will be required for determining and documenting equipment, personnel and training requirements to support the GIS program envisioned in the Needs Analysis.

Time required—1 person-month.

TASK 5 *Estimate Costs and Benefits*: Two-person weeks should suffice for the cost and benefit calculations.

Time required—0.5 person-months.

TASK 6 *Present the GIS Feasibility Study*: Two person-weeks should be allotted for preparing a final draft of the GIS Feasibility Study. Two weeks should be allocated for preparing for and conducting workshops, and two should be allocated for revising the final draft of the study following the workshops.

Time required—1.5 person-months.

Consultant Qualifications

The consultant provided to execute these tasks should have the following qualifications:

- At least 12 years of experience as a management consultant with a specialization in surveying, mapping, remote sensing and geographic information system development.
- At least 5 years of experience working in a surveying, mapping, remote sensing or GIS production organization.
- At least 5 years of experience working in developing countries.
- A demonstrable track record in assisting clients with the development of geographic information systems and/or the management, development and operation of sizeable geographic information systems.
- An education at the college level involving the study of one or more of the following disciplines: computer science with an emphasis on GIS technology, survey, mapping, organizational development or public organization management.

Attachment I: Satellite Imagery and Basin Boundary Mapping

During the past decade the quality and availability of satellite imagery have improved to the point where WSCU should give serious consideration to the inclusion of satellite images in its geographic information system. As satellite images could well be the most accurate and most current data source available for many of SADC needs, WSCU should investigate their suitability for this undertaking as part of the RBM Data Requirement and Availability Survey.

Attachment II summarizes current trends in satellite image acquisition and distribution and reports on the status and technical capabilities of most operational and planned remote sensing satellites.

Radar Imagery and Basin Boundary Mapping

Canada's RADARSAT satellite, with its cloud penetrating capability, permits data acquisition in areas that are persistently cloud-covered. For technical information about the satellite, see Attachment II.

During the last two years, Intermap Technologies Ltd. of Calgary, Alberta, Canada has developed a software technology, TOPOSAR, for producing Digital Elevation Models (DEM) and Ortho-Rectified Images (ORI) from RADARSAT data. Using TOPOSAR the company can generate DEM and associated image products for almost any location in the world. Intermap's claims that it can deliver DEM with a vertical accuracy of between 10m and 30m depending on the type of terrain and ground control available. DEM post spacing varies from 30m to 50m.

Intermap's process for generating DEMs allows satellite images to be geo-coded and ortho–rectified to remove any distortion due to terrain features. These rectified images can then be used to produce basemaps for a geographic information system, or as the geobase for a raster–based GIS. Depending on the type of the raw imagery used, the resultant ORIs will have a pixel size of either 6.25m or 12.5m (absolute horizontal accuracy of 12.5m). These data are suitable for creating mapping products down to a scale of approximately 1:100,000.

DEM and ORI could prove invaluable when seeking to establish river basin boundaries in out–of–the–way areas that have never been adequately mapped or for which current maps are not otherwise available. The suitability for these products for use in developing the RBM spatial database should be investigated as part of the RBM Data Requirement and Availability Survey. DEM can be used to create the contour lines that will be needed to identify the ridgelines that form the boundaries of the various river basins. They and the ORI can be combined to create perspective views of the basins and to generate thematic maps showing landuse/landcover.

RADARSAT DEM of the entire SADC area having 10-15 meter vertical accuracy and 50-meter posting will cost between $3.00 and $6.00 per square kilometer.

DEM and ORI having 1–2 meter vertical accuracy, 2.5 meter horizontal accuracy and 5 meter posting and produced with Intermap's STAR–3i radar mapping system will cost between $50 and 100 per square kilometer.

These are planning figures only. Actual costs will depend upon the size of the area covered, the location of the home base of the aircraft acquiring the data, ferry distance to and from the acquisition sites and related on–station time. More specific information can be obtained from the Director, Global Terrain Business Development, Intermap Technologies, Inc., Calgary, Alberta, Canada T2P 4G8. (Phone: 403-266-0900; Fax: 403-265-0499; info@intermaptechnologies.com).

Subsurface Water Determination

As the location of subsurface water depends on the underlying stratigraphy, acquifers and subsurface rivers cannot be accurately located from simple topographic maps and surveys. If WSCU desires that these features be included in the RBM–GIS, it will have to locate and obtain geologic and soil maps and other records depicting the results of past geologic surveys and hydrologic investigations. This subject is a logical topic for discussion while putting together the Needs Analysis and Data Requirement and Availability Survey. The introduction of this topic by some members of the WSCU at this time clearly points to the necessity for the preparation of a comprehensive Needs Analysis and the involvement of the ultimate users of the RBM–GIS in that process.

Those unfamiliar with the use of remotely sensed satellite data for natural resource and environmental management should consult "The Remote Sensing Tutorial an Online Tutorial." It is available at http://rst.gsfc.nasa.gov. Section 2: Geologic Applications I – Stratigraphy & Structure discusses the use of satellite data in geologic studies for waterpocket fold mapping and groundwater surveys. The Applied Information Sciences Branch (Code 935) NASA Goodard Space Flight Center is the sponsor for this tutorial. A CD version is available for $11.00.

Attachment II: Current Remote Sensing Platforms

Remote sensing is the science of getting information about an object by acquiring data with a device that is not in contact with that object. The human eye is a remote-sensing device, and so is the ear.

Remote-sensing satellites collect image data either actively or passively. Radar satellites collect data actively by sending a known signal from the satellite to the earth and measuring the portion of the signal that is returned. A passive device measures incoming energy. That is, energy that starts at the sun and is reflected by the object, or energy produced at the object as a function of its temperature. Every object reflects electromagnetic energy in various wavelengths determined by the object's physical and chemical structure. When data from the different wavelengths are combined (by a computer), the resulting images reveal far more about the Earth's surface than do images that record only visible light.

Remote Sensing Systems Characteristics

Important attributes of satellite remote-sensing systems include spatial resolution, spectral coverage, and temporal frequency.

Spatial resolution describes the level of detail, or smallest size of an object, which can be identified. Present civil systems have spatial resolutions in the range from 10 meters to 4 kilometers. Some data with spatial resolution less than 10 meters is currently commercially available from systems originally intended for military use, such as the Russian satellite cameras.

Spectral coverage refers to how many different colors and different parts of the spectrum are measured. Systems today make from one to seven measurements of light energy for each target area.

Temporal frequency refers to the cycle of coverage or how often data are collected from a particular satellite. The temporal frequency of operating remote sensing satellites ranges from one satellite pass every month to two every day.

Remote sensing systems make trade-offs between spatial resolution, spectral coverage, and temporal frequency. For some uses, fine spatial detail is crucial; an example is cartographic mapping. In other cases, information is needed frequently, but does not require as much detail. For example, weather data are needed several times a day. Other times, having more measurements in the spectral domain provides the appropriate information. For example, when the health and vigor of plants in a field or throughout a region is desired, spectral coverage is important, spatial detail and some temporal frequency can be forfeited.

Remote Sensing Satellite Operation

Remote sensing for Earth observation is an international activity. The U.S. LANDSAT program launched its first satellite in 1972, and is the oldest Earth observation program. Today, India, France, Russia, Japan, and the European Space Agency also operate Earth observation satellites. Agricultural, natural resource, ecological and atmospheric monitoring are areas that have been served by government developed satellite systems offering 30-meter and lower resolutions for over two decades.

In 1994, Lockheed Martin Corp. and E-Systems, Inc. chartered Space Imaging. Their purpose was to transform years of market analysis and technology development into a viable business capable of developing new markets for high-resolution Earth imagery collected by satellite. That same year, the issuance of U. S. Presidential Decision Directive 23 gave the go-ahead to Space Imaging to launch the world's first commercial one-meter resolution satellite and offer its imagery and derivative Earth information products to the global commercial marketplace.

In 1995, Mitsubishi Corporation became a partner in Space Imaging. Since then, Space Imaging has added Singapore's Van Der Horst Ltd., a service engineering and infrastructure development group, and Halla Business Group, a Korean industrial giant to its list of investors. Space Imaging's European operation is based in Athens form which it does business as Space Imaging Europe S.A. (SIE).

Space Imaging has since acquired the Earth Observation Satellite Company (EOSAT). EOSAT was created to commercialize the U.S. Government's LANDSAT program and for over a decade provided high-quality imagery of the Earth to the global commercial marketplace. The EOSAT purchase enabled Space Imaging to benefit from an established, worldwide distribution network and access to imagery from several leading space-based imaging systems. These include the Indian government's Remote Sensing (IRS) satellite program which, with its five-meter resolution, is among the highest resolution commercially available satellite imagery today; the Canadian Space Agency's RADARSAT; the Landsat satellites; Japan's JERS satellite system; and the European Space Agency's ERs synthetic aperture radar (SAR) satellite.

In 1999, Space Imaging intends to launch its first advanced commercial imaging satellite, IKONOS-1. This satellite will produce images that display objects on the Earth's surface as small as one meter in diameter.

Space Imaging based in Thornton, Colorado, USA, envisions a huge potential market developing as a result of being able to provide this order-of-magnitude increase in accuracy and expanded information through its growing constellation of commercially developed satellites. For example, Space Imaging believes competitive agriculture marketplace can benefit from the transition to imagery-aided "precision farming." Frequent monitoring of crop growth and health, as well as early identification of diseases and blights, can significantly improve crop yields. In forestry, one-meter resolution will not only allow the identification of general areas of diseased and stressed vegetation, but can actually inventory forests down to individual trees. It can also determine the most visibly unobtrusive places to cut.

Space Imaging believes its CARTERRA[14] images will also be used to police illegal tree cutting and monitor the deforestation of rain forest areas. They also envision that the availability of high-

[14] CARTERRA is Space Imaging's trade name for its line of digital image products produced from remotely sensed data.

resolution, content-rich information will become an important tool for tracking the path of toxic and chemical spills and determining their long-term impacts on wildlife habitats and vegetation.

Remote Sensing Satellites

Indian Remote Sensing Satellite

The Indian Remote Sensing (IRS) Satellite, IRS-1C, was launched in December 1995. This satellite has two interesting sensors on board, LISS-3 and WiFS (Wide Field Sensor). LISS-3 covers the green, red and the near infrared portion of the spectrum with a spatial resolution of 23m, re-sampled to 20m. An additional infrared band is available with a spatial resolution of 70 m. Panchromatic data is recorded with a spatial resolution of 5.8m, re-sampled to 5m. WiFS data has a spatial resolution of 188m and only records the red and the near infrared band, but the swath-width covers 810 km. Its Wide Field Sensor is ideal for scanning large areas of the Earth's surface with high frequency and thus for collecting information for environmental and agricultural monitoring, natural resource management and land use planning.

The image size is 141 km x 141 km, but customers can buy quadrants of 72km x 72km. By combining its Landsat-like spectral characteristics with its wide-area coverage and high-resolution imaging capabilities, IRS-1C is a multi-purpose satellite that has applicability for a wide range of applications. Since IRS-1D was launched on 29 September 1997, the revisiting cycle has been increased from 24 to 12 days. Its equipment is identical to that onboard IRS-1C enabling the production of 5.8-meter resolution images twice as often as was previously possible with the IRS-1C alone.

India's IRS-P3 satellite, which collects imagery with 200-meter resolution, is ideally suited for oceanographic and atmospheric research, vegetation and land use mapping, and ecological monitoring.

The following Table shows the main features of the IRS-1C and 1D satellite's sensors.

Band	Spectral Range (μm)	Resolution (m)
2 (Green)	0.520 – 0.590	20
3 (Red)	0.620 – 0.680	20
4 (NIR)	0.770 – 0.860	20
5 (SWIR)	1.550 – 1.700	70
Panchromatic	0.520 – 1.700	5.8

Space Imaging has entered into a 10-year partnership agreement with ANTRIX Corp. Ltd. of India, the commercial marketing arm of the Indian Space Research Organization, to have exclusive distribution rights to its Indian Remote Sensing (IRS) satellite imagery. Through this agreement, Space Imaging has access to a vast array of advanced imagery products from the IRS constellation. The current constellation of five satellites (some introduced as early as 1988) is expected to grow by at least seven through the year 2004. This will make the IRS program one of the most robust commercial programs in the world. The IRS series provides information tools for a wide range of resource management applications.

Future plans call for the development of IRS satellites which will provide comprehensive solutions to a variety of needs. On the drawing board are radar and optical systems for oceanographic, climatic and atmospheric applications; a 2.5-meter resolution, hyperspectral sensor for advanced environmental applications; and a six-meter resolution system that will be used for enhanced land applications requiring map-level accuracy.

IKONOS-1

IKONOS-1 is a satellite being developed for and by Space Imaging. This satellite will provide commercial imagery with equivalent to aerial photography taken at an altitude of 3,000 meters and accurate enough to replace traditional 1:2,500 scale line maps. The launch of IKONOS-1 in June 1999 was unsuccessful. IKONOS-2, an identical twin to IKONOS-1, will be launched later that year.

IKONOS-1 will supply both black and white images with one-meter resolution and multispectral (color) images with four-meter resolution. It incorporates a key color-enhancing algorithm that allows multispectral information to achieve one-meter sharpness. The satellite will also collect data in the near-infrared band at four-meter resolution. The combination of data collected in each of these four bands will provide information for applications that require analysis, identification, characterization and other monitoring capabilities for natural and cultural features.

IKONOS-1 will be capable of pointing to a new target and stabilizing itself within a few seconds. This agility will give it robust imaging capabilities. These capabilities range from sweeping a single 11 kilometer strip as the satellite passes directly overhead to following a meandering coastline or power line. The satellite will be able to image a specific location as it passes over the horizon and then tilt back to image the same spot just before it disappears again. This latter capability will provide stereo imaging of the selected target area.

The satellite’s performance will be enhanced by the fact that the satellite’s polar orbit will allow it to traverse the planet every 98 minutes and download as many as 600 images per day, with each image measuring 11x11 square kilometers. The satellite will thus be able to collect vast areas of imagery with unprecedented speed. The on-board tape recorders will have the capacity to store images covering 12,100 square kilometers. The satellite’s sun-synchronous orbit will allow it to cross the equator at the same time—between 1000 and 1100 hours—in every orbit and will insure image consistency and quality. It will also allow specific sites to be revisited with regularity allowing information-rich, change-over-time analysis.

The following Table shows the main features of the IKONOS satellite's sensors.

Band	Spectral Range (µm)	Resolution (m)
1 Blue	0.450 to 0.520	4
2 Green	0.520 to 0.600	4
3 Red	0.630 to 0.690	4
4 NIR	0.760 to 0.900	4
Panchromatic	450 to .900	1

OrbView

OrbView-3 is owned and operated by ORBIMAGE (Virginia, USA). It is another satellite that will offer very high resolution optical imagery. This satellite will provide 1 and 2-meter resolution panchromatic and 4-meter resolution multispectral imagery on a real-time basis worldwide. Launch is scheduled to take place in 1999. The spectral characteristics of the panchromatic and 4 multispectral bands on OrbView-3 are identical to those of IKONOS (see above). More information can be found at http://www.orbimage.com/satellite/orbview3/ orbview3.html.

OrbView-4, planned for launch in 2000, will continue ORBIMAGE's line of high-resolution satellites. It promises the same possibilities as OrbView-3 but, in addition, it will be the world's first satellite to acquire hyperspectral imagery. More information can be found at http://www.orbimage.com/satellite/orbview4/ orbview4.html.

More information on OrbView satellites can also be found at http://seawifs.gsfc.nasa.gov/ and at http://www.orbimage.com/. Launch information can be found at http://www.orbimage.com/ news/launch/launch.html.

Landsat 7

The launch of Landsat 7 is scheduled for 15 April 1999. The general characteristics of the satellite will be the same as those of its predecessors, i.e. 185 km swath width, 16 day repeat cycle, 705 km orbit altitude and an equatorial crossing around 1000 hours local solar time. Like earlier Thematic Mapper sensors, the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) will provide data in six visible, near infrared (NIR) and short wave infrared (SWIR) bands. In addition, ETM+ will provide improved resolution for the thermal infrared (TIR) band (60 m vs. 120 m) and a panchromatic band with 15m resolution. The onboard tape drive will store 100 images.

The following Table shows the main features of the Landsat 7 sensors.

Band	Spectral Range (µm)	Resolution (m)
1 (Blue)	0.450 – 0.515	30
2 (Green)	0.525 – 0.605	30
3 (Red)	0.63 – 0.69	30
4 (Near-infrared)	0.75 – 0.90	30
5 (Short-wave infrared)	1.55 – 1.75	30
6 (Thermal infrared)	10.40 – 12.50	60
7 (Mid infrared)	2.35 – 3.09	30
Panchromatic	0.520 – 0.900	15

SPOT 4

SPOT 4 was launched on 24 March 1998. The SPOT 1 and SPOT 2 are still operating. The first satellites of the SPOT series have three bands covering the green, red, and near infrared portion of the spectrum and a panchromatic band. The short-wave infrared band is the major development for SPOT-4. SPOT 4 carries the European VEGATATION instrument that operates in the same four spectral bands as the high-resolution visible infrared bands, but at a reduced 1.16km spatial resolution. The image size of a SPOT scene is 60 km x 60 km.

The following Table shows the main features of the SPOT 4 sensors.

Band	Spectral Range (µm)	Resolution (m)
1 (Green)	0.500 – 0.590	20
2 (Red)	0.610 – 0.68	20
3 (Near-infrared)	0.780 – 0.890	20
4 (Short-wave infrared)	1.58 – 1.75	20
Panchromatic	—	10

EarlyBird and QuickBird

EarlyBird, another commercial high-resolution satellite was launched on 24 December 1997. Two-way communication was lost after a few days of normal operation. Earthwatch Inc. (Colorado, USA) operates the satellite. It featured cross-track and along-track viewing instruments that should have allowed a revisiting time of two to five days, depending on latitude. The field of view was ±280 km, within which 3x3 km or 15x15 km images can be acquired with a panoramic resolution of 3 meters.

EarlyBird is to be followed in 1999 by QuickBird, a satellite that will feature 0.83 meter panchromatic and 3.2 meter multi-spectral sensors. Sensor characteristics are as shown in the following Table.

Band	Spectral Range (µm)	Resolution (m)
1 (Blue)	0.450 – 0.520	4
2 (Green)	0.520 – 0.600	4
3 (Red)	0.630 – 0.690	4
4 (NIR)	0.760 – 0.890	4
Panchromatic	0.450 – 0.900	1

KVR-1000 Images

KVR images have the best spatial resolution of any civilian remote sensing image data currently available. These images are photographic pictures taken from low altitude Kosmos satellites. These satellites do not return to Earth after their mission, only the camera and the film come down by parachute. The customer buys digital data sets derived from scanning these panchromatic photos.

The images have a central projection, however, due to a much higher altitude when compared with airplanes, effects such as differential shading are negligible. Satellites equipped with a KVR-1000 camera that return to earth after their mission are now operational. Aerial Images, Inc. and SOVINFORMSPUTNIK recovered the film together with the imaging satellite on 3 April 1998. This satellite circled the Earth for 45 days taking highly detailed images of the Southeast United States and major population centers around the world.

These companies plan to provide images with 2-meter resolution. The processed images are available on TerraServer, which is an on-line catalogue showing the actual images of an area. TerraServer holds imagery covering more than 2 million square kilometers of the surface of the earth. Users can browse full scenes to determine if the particular area of interest is available. They can also view these images.

MOMS-02

The MOMS-02 sensor was installed on the Russian space station MIR. This sensor can provide panchromatic images with 4.5m spatial resolution and multispectral images of 13m resolution. The sensor, using the push broom principle (like a photocopy machine), can look forward, downward and backward through different objectives. This allows on time stereo images.

Band	Spectral Range (μm)	Resolution (m)
1 (Blue)	0.440 – 0.505	13.5
2 (Green)	0.530 – 0.575	13.5
3 (Red)	0.645 – 0.680	13.5
4 (NIR)	0.770 – 0.810	13.5
Panchromatic	0.520 – 0.760	4.5

RADARSAT

The Canadian Radarsat 1 was launched in November 1995 and is working well. The satellite carries a C-band SAR that is capable of acquiring data in several different beam modes (Fine, Standard, Wide, Extended High, Extended Low, ScanSAR Narrow, ScanSAR) and at several different incidence angles (10°- 59°). Polarisation is HH (Horizontally transmitted, Horizontally received), the repetition cycle 24 days and it has descending equator crossing at 06.00.

Data acquired within the geographical coverage area of the Tromsö Satellite Station (TSS) in Norway are processed and distributed by TSS in co-operation with the Swedish Space Corporation. E.g. Radarsat SAR-data from TSS are used by the icebreaker service operated by SMHI in Norrköping. The data are processed at SMHI and then transmitted to Swedish and Finnish icebreakers to be used as a guidance for theirs missions. Information about RADARSAT can be found on http://radarsat.space.gc.ca/ (http://radarsat.space.gc.ca/) and on http://www.tss.no/radarsat/ (http://www.tss.no/ radarsat/).

JERS-1

JERS-1, the Japanese Earth Resource Satellite was launched on 11 February 1992. On 12 October 1998 a malfunction occurred, and the Okinawa Station terminated the operation of the satellite.